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AIR POLLUTION CONTROL IN THE PRIMARY ALUMINUM INDUSTRY

VOLUME II. APPENDICES

SINGMASTER AND BREYER

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

JULY 1973

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AIR POLLUTION CONTROL IN THE PRIMARY ALUMINUM INDUSTRY

VOLUME II OF II

APPENDICES

23 July 1973

SINGMASTER & BREYER
235 East 42nd Street
New York, N.Y. 10017

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APPENDICES

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* EPA Sampling information contained in these sections.

Appendix 1A

Data Acquisition Questionnaire

Most of the data from which the understanding of the United States aluminum industry statistics and control technology were derived came from responses to a detailed and comprehensive questionnaire submitted to all producers. In addition to general information about each plant and its surroundings, the questionnaire asked detailed information about processes and emission controls in 14 process areas which may be associated with aluminum smelters. The first three of these 15 sections are included in this appendix; they are representative of questions in all process areas.

DATA ACQUISITION QUESTIONNAIRE

For

Engineering & Economic Study of Emissions Control in The Primary Aluminum Smelting Industry

By

SINGMASTER & BREYER

For

THE NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

under

Contract No. CPA 70-21

Budget Bureau No. 85S-70012
Approval Expires May, 1971

PART I

1.0 Format

This questionnaire is designed to obtain pertinent data on the emissions control practice and costs of the respondent plants.

Part I of the questionnaire lists the data coding structures which are used to identify the plant elements reported on, the collection/control systems utilized in these plant elements, and the individual control units which make up the various control systems.

Part II contains separate questionnaire sections applying to the plant elements listed and coded in Section 2.0 below, and utilizes the control system coding to reference the data. It is intended that only the sections applicable to a specific plant be completed, and that other sections be disregarded.

Respondents are requested to carefully read the explanation of the control system coding given in Part I, as its proper application is very important in obtaining meaningful information from Part II.

2.0 Process Emission Designation Codes

In primary aluminum smelter operation, effluents are generated both by process operations and by physical materials handling. To identify the process operations which may be involved in a given reduction plant complex, including those connected with support operations, the following check list is presented.

To provide complete coverage of emission data for a given plant, the respondent is requested to indicate, against the appropriate process code, the processes carried out in his plant; one section of Part II should be completed for each plant element so checked, identified by the appropriate process code designation.

Process Code	Located at Smelter Site	Process Designation
2.00	☐	General Information
2.10	☐	Primary Aluminum Smelting (Potlines)
2.20	☐	Carbon Anode Prebake
2.25	☐	Prebake Carbon Anode Rodding
2.30	☐	Carbon Anode Mix - Soderberg Paste
2.40	☐	Carbon Cathode Mix - Monolithic
2.50	☐	Carbon Cathode Block - Prebake
2.55	☐	Calcining
2.60	☐	Aluminum Casting and Dross Reclaim
2.70	☐	Aluminum Fluoride Production
2.75	☐	Hydrogen Fluoride Production
2.80	☐	Cryolite Production
2.85	☐	Pot Relining and Bath Reclaim
2.90	☐	Water Treatment Plant
2.95	☐	Steam and/or Energy Generation

3.0 Effluent Control System Codes

For the purpose of this questionnaire an effluent control system is defined as the collection ducting gathering and carrying effluents to a single or multistage arrangement of equipment in which gaseous and/or particulate separations are made from the conveying air stream. The effluent loading of the system is taken at the inlet to the first control unit. The emission from the system is the release to atmosphere of the last control unit.

The control system code employed is a six-digit number which can be used to uniquely designate the individual system as a whole, the stage configuration of the control equipment, and the type of equipment used in a given stage.

The first digit in the code is always 3, identifying the code reference as a control system.

The second two digits identify the specific system for which the data is given. These digits will be assigned by the respondent, sequentially from 01, to the individual systems used throughout the entire plant.

The fourth digit identifies the particular stage in the unique system when the data refers to the control units, as well as to the system as a whole. For collection systems without control, as for example a building ventilation system from which pollutants may be emitted, the fourth digit will be 0.

The final two digits designate the type of unit (or parallel units) in the stage.

Where the reference is made only to the system, the unused digit places are indicated by XX, e.g. 3.06.2.XX or 3.06.X.XX.

The listing following gives the fifth and sixth digits assigned to various types of control unit.

To illustrate:

3.06.2.10 represents
unit - dry cyclone
stage - second
sixth system
control

4.0 Use of Available Data

The data requested by this questionnaire is expected to be furnished if it is available from normal plant operating records (or design criteria in the case of plants without an operating history). Where data requires extensive measurement or analysis not normally practiced, this fact should be noted on the appropriate questionnaire sheets. Efforts to make the data reporting as complete as possible will be appreciated.

5.0 DEFINITIONS

CONTROL SYSTEM	Apparatus for gathering and treating effluents or contaminants (usually dispersed in air or a gas stream) released from a process or materials handling operation. Included in a control system are: i. Collection equipment consisting of hoods, ductwork, instrumentation and fans required to move the gas stream from its point of generation and, ii. Removal equipment such as cyclones, scrubbers, etc. together with the necessary auxilliary pumps, fans, instrumentation, etc. required to operate these units.
EFFLUENT	Pollutant in the form of gaseous compounds or particulate matter (usually dispersed in air or a gas stream) which is released from a production or material handling process.
EMISSION	A pollutant which is released to the atmosphere.

Plant Identification _____
Process Code 2.00 General

PART II

PRIMARY ALUMINUM SMELTER

General Information

Plant Identification _______
Process Code 2.00 General

This part of the questionnaire, designated by the code number 2.00, concerns general information about your smelter which characterizes the plant as a whole and helps to put into perspective the detailed information about the various effluents, controls, and emissions which is asked in other sections of the questionnaire. Please answer the questions on form 2.00-1 with brief statements or sketches as appropriate.

Plant Identification ______
Process Code 2.00   General

1. Please describe briefly the smelter location and characteristics of the immediate surroundings.

2. Please show on a sketch map the extent of owned or controlled property, and location on the property of the major components of the smelter.

3. What are the prevailing winds and frequency of temperature inversions?

4. By what means is the bulk of your electric power generated and where is the generation station?

5. By what means are alumina, cryolite, and aluminum fluoride delivered to the plantsite?

6. Are there any neighboring process industries which may emit fluorides to the atmosphere?

7. Please prepare a brief statement on the money your company has spent and is spending on research and development for air pollution control techniques and equipment. If you can associate

Plant Identification ______
Process Code 2.00 General

an R & D cost with a specific device or process, please point this out. Please differentiate between money spent at the corporate level for the benefit of the whole company from that spent at the plant to solve local problems.

Plant Identification ______
Process Code 2.10 Potlines

PART II

PRIMARY ALUMINUM SMELTER

(Potlines)

Plant Identification _____
Process Code 2.10

PRIMARY ALUMINUM SMELTER

1.0 Description

The primary process is defined as the Hall Heroult Electrolytic reduction of alumina to aluminum. It includes the buildings and equipment required to house and operate it and to transport materials and energy to and from it. It is carried out in the area enclosed by the gross perimeter of the potline buildings, and is designated Process Code 2.10 in this questionnaire.

2.0 Physical Parameters - Plant Section

The intent of this section of the questionnaire is to obtain information concerning equipment type and configuration and building ventilation, insofar as these are concerned with effluent generation, collection and control. This information should be provided by filling in the blank spaces on form 2.10-1. In plants where there are uncontrolled roof monitor emissions, please assign a control code number to this system as well as to the controlled systems. In the last section of this part of the questionnaire, uncontrolled emission systems will be designated by a zero in the third digit of the code number.

Plant Identification____
Process Code 2.10 Potlines

Form 2.10-1
Physical Parameters

	POTLINE NUMBERS						
	1	2	3	4	5	6	7
1. Building Nos.							
2. Air Flow into bldgs., scfm							
3. Avg. No. operating pots per line							
4. Type of pot							
5. Control System Codes*	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX
	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX
	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX
	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX	3.__.X.XX

Remarks

*1. The two-digit numbers to be entered identify the individual effluent control systems.

2. If two potlines share a control system, enter the same number under each line.

3. Please assign a system code number to gases which leave the buildings without emission control such as through roof monitors or a stack.

Plant Identification _____
Process Code 2.10   Potlines

3.0 Production

Objectives of this survey include the prorating of air pollution control system costs to the output of primary product, and the provision for some measure of the future magnitude of control requirements and costs. The intent of this section is to obtain actual past primary aluminum production data and best estimates of expected future output. This information may be provided by filling in the blank spaces provided in the following table.

PRODUCTION, ACTUAL & FORECAST

Short Tons, Net Aluminum*

YEAR	PRODUCTION
1967	
1968	
1969	
1970	
1971	
1972	
1973	
1974	
1975	
1976	

*Exclude Alloy Materials Additions.

Qualifying Remarks: (Use extra sheet if required)

Plant Identification ____
Process Code 2.10

4.0 Materials into Process

The intent of this section is to obtain a measure of the quantities and forms in which materials must be handled. This information also will serve as a basis for prorating effluent control cost estimates on the basis of material tonnages handled.

Please indicate the approximate annual tonnage of input raw materials.

Annual Raw Material Input

Material	Short Tons
Alumina, Sandy	
Alumina, Floury	
"F" Content of Floury	
Total "F" other Materials	
Anode Carbon, Prebake	
Anode Soderberg Paste	

Plant Identification _____
Process Code 2.10   Potlines

PRIMARY ALUMINUM SMELTER

5.0 Materials Handling

The intent of this questionnaire section is to describe the systems used to transport materials to and from the potlines and to control effluents and emissions from such transport, noting specifically:

a) Existence of separate or common control systems at these transfer points.

b) Efficiency of the specific control systems.

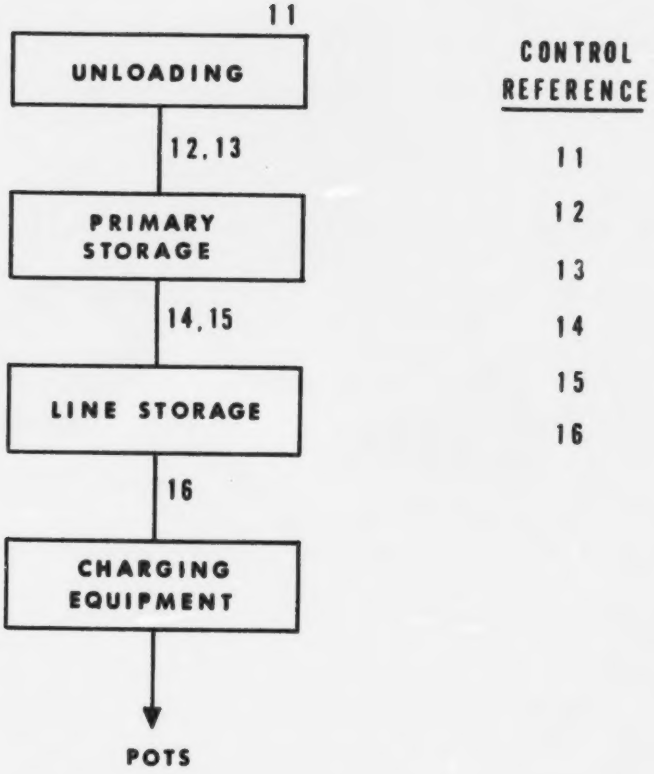
The material handling system is defined as the equipment sequences used to transport materials to and from the area bounded by the gross perimeter of the potlines. A supplementary descriptive line flow diagram showing control references for each material handling system, as illustrated in Fig. 1, is suggested for identification and clarification.

The performances of the separate control systems serving material handling transfer points are reported in forms 2.10-3,-4 and -5.

FIGURE 1

MATERIAL HANDLING SYSTEM
(EXAMPLE)

PROCESS CODE: 2.10


11
UNLOADING
12,13
PRIMARY STORAGE
14,15
LINE STORAGE
16
CHARGING EQUIPMENT
POTS
CONTROL REFERENCE
11
12
13
14
15
16

Plant Identification _____
Process Code 2.10 Potlines

PRIMARY ALUMINUM SMELTER

5.0 Materials Handling (Cont'd)

For each material handled in your plant as noted in Section 4.0 please use a separate sheet of form 2.10-2 to indicate the material type, handling methods and the effluent control systems involved.

Plant Identification ____ Form ______-2 ___of ___
Process Code ______ Name __________ Materials Handling Transfer

Materials Handling Effluent Points

Name of Material _________________ %F _________________

Material Form Bulk ___ Pieces____
Bagged ___ Liquid____
Pallets ___ Other ____ Specify _______________

*Control Reference	Handling Method	Control Code
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX

Remarks:

*Please identify by number on a block flow diagram.

Plant Identification _____
Process Code 2.10   Potlines

6.0 Effluent and Emission Parameters

To obtain a full description of the control systems, their performance, and cost, a set of 3 data forms (-3, -4, and -5) is requested to cover each separate control system used in this process area.

The separate systems have been previously identified by code on forms -1,and -2.

For each of these systems, please fill out a separate sheet of form -3 giving the requested data on collected effluents entering the first control stage and, if available the data for intermediate control stages prior to final emission release. (For Soderberg pot systems the burner is treated as the first stage). Control units in parallel are to be considered as a single stage. Forms are to be completed with available data in units normally employed; where data is not available, the fact should be noted.

For each of the control systems please fill out a separate sheet of form -4 giving the requested data on emissions from the last stage of control.

Plant Identification _____
Process Code 2.10   Potlines

6.0 Effluent and Emission Parameters

Where control systems discharge through a stack, the stack should be treated as a separate system, perhaps in series with others, and forms -4 and -5 should be completed for the stack.

For each stage in the separate control systems specific information is requested concerning the operating parameters and costs of the units or group of parallel units constituting this control stage. You are requested to provide this data by completing a separate sheet of form -5 for each stage of each control system specified.

Plant Identification ____
Process Code ____________ Name ___________

Form ______-3; __of__
Control System Input

Effluent Entering Control System

Control System Identification, Stage, and Type 3.___.___.___.___
(Report data common to identical systems on one sheet and list code numbers of identical systems.)

Effluent Parameter	Units	Range		Average
Temperature,				
Gas Flow Rate,	scfm			
Nitrogen concentration,				
Oxygen concentration,				
Carbon Dioxide,				
Carbon Monoxide,				
Sulfur Dioxide,				
Sulfur Trioxide,				
Fluoride as F,				
Hydrocarbons,				
Pitch condensible at 32°F				
Total Particulates,				

Particulate Composition, w%	
Alumina	
Fluoride as F	
Carbon	
SO_3	

Size Distribution w%	
< 5 μ	
< 10 μ	
< 40 μ	
<100 μ	
>100 μ	

Other identical control systems ______________________________

Remarks:

Plant Identification ____
Process Code ______ Name ____________

Form ______-4; __of__
Control System Emission

Emission from Last Stage of Control

Control System Identification Stage and Type 1/ 3.__.__.__.

Effluent Parameter	Units	Range		Average
Temperature,				
Gas Flow Rate,	scfm			
Nitrogen concentration,				
Oxygen concentration,				
Carbon Dioxide,				
Sulfur Dioxide,				
Sulfur Trioxide,				
Fluoride as F,				
Hydrocarbons,				
Pitch condensible at 32°F				
Total Particulates,				

Particulate Composition, w%		Size Distribution, w%	
Alumina		< 5 μ	
Fluoride as F		< 10 μ	
Carbon		< 40 μ	
SO_3		< 100 μ	
		> 100 μ	

1/ Emissions without control, such as may come from roof monitors, should be designated 3.__. 0.XX

Plant Identification_____
Process Code_____ Name ________

Form _____-5__ of__
Control Equipment

Operating Parameters and Costs for

Effluent Control Equipment

Control Unit Code Number: 3.__.__.__

Number of identical units in parallel at this stage________

Manufacturer ____________________

Catalog number or other description ___________________________

Total Gas Flow:	Actual cfm	Pressure Drop, in. H_2O
min	__________	____________
max	__________	____________
AVg	__________	____________

Total Fans: Number _____ cfm _____ HP _______

Liquor Flow, gpm _______ Composition of Solvent __________

F concentration in discharge from control system, ___________

Disposition of separated HF,_____________________________

Total Pumps: Number _____ gpm _____ psi _____ HP ____________

Total Particulates Separated, ______________________lb/hr.
Identification ___________________________
Destination: Discard _____, Recycle _____, where? _________

Value of recovered fluorine, $_____per ton of separated F.

*Installed Cost of Collection Equipment, hoods, enclosures. ductwork, etc. $ ____________Year installed ____________.

*Installed Cost of Removal Equipment, $ ___________Year_______.

Annual Operating Costs:
Power, $ ______________ Chemicals $_______________ Parts $ _______

Operating labor $___________________Maintenance labor $___________.

*Installed costs include purchase costs of all fans, pumps, drivers, piping, structurals, ductwork, electrical accessories, instrumentation, etc., installation labor costs, and engineering costs paid directly by the smelter operator. Costs of collection and removal equipment are additive to represent total costs of control systems.

Plant Identification _____
Process Code 2.20 Prebake Anodes

PART II

PREBAKE ANODES

Plant Identification _____
Process Code 2.20   **Prebake Anodes**

PREBAKE ANODES

1.0 Description

This process grouping comprises the buildings and equipment required to receive, prepare and store carboniferous materials; to combine and form the materials into anodes; to bake and clean the anodes.

2.0 Physical Parameters - Plant Section

The intent of this section is to obtain information on equipment type and configuration, and unit operations, insofar as these affect effluent generation and collection. Please enter the requested information in the blank spaces on form 2.20-1.

Plant Identification _____
Process Code 2.20 Prebake Anodes

Form 2.20-1 (cont'd)
Physical Parameters

C. Pressing

Average number of presses in operation__________________.

Average operating time per press, min/day ______________.

Press effluent control codes, 3.__.X.XX, 3.__.X.XX

D. Baking

Average number of furnaces in operation________________.

Average operating time per furnace, hr/day_____________.

Average number of tunnel kilns in operation____________.

Average operating time per kiln,hr/day_________________.

Type of fuel: Natural gas_____, Fuel oil_____, Grade_____.

Fuel rate per ton of baked anodes, _____________________.

Average sulfur content of fuel_____percent by weight.

Effluent control codes, 3.__.X.XX, 3.__.X.XX, 3.__.X.XX.

Plant Identification ______
Process Code 2.20   Prebake Anodes

3.0 Production

The intent of this section is to provide an additional measure of the cost effectiveness of effluent collection and control systems in terms of the weight of carbon anode product. Please enter the requested estimates in the blank spaces of the following table:

	ANNUAL SHORT TONS	
YEAR	Green Anodes	Baked Anodes
1967		
1968		
1969		
1970		
1971		
1972		
1973		
1974		
1975		
1976		

Plant Identification _____
Process Code 2.20   Prebake Anodes

4.0 Raw Materials

The intent of this section is to obtain a measure of the quantities and forms in which raw materials must be handled. This information entered in the table below to provide a basis for prorating collection and control costs estimates to tonnage of materials handled.

ANNUAL RAW MATERIALS

MATERIAL	SHORT TONS
Green Petroleum Coke	
Calcined Petroleum Coke	
Spent Anode Butts	
Coal Tar Pitch H S P Solid	
Liquid	
Coal Tar Pitch L S P	
Coal Tar	
Pet. Base Pitch H S P Solid	
Liquid	

Please furnish typical analyses for the above materials.

Plant Identification _____
Process Code 2.20 Prebake Anodes

5.0 Material Handling

The intent of this section is to describe the systems used to transport materials to and from the Carbon Anode Prebake Process and to control effluents and emissions from such transports, noting specifically:

a) Existence of separate or common collection and control systems at these transfer points.

b) Efficiency of the specific collection and control systems.

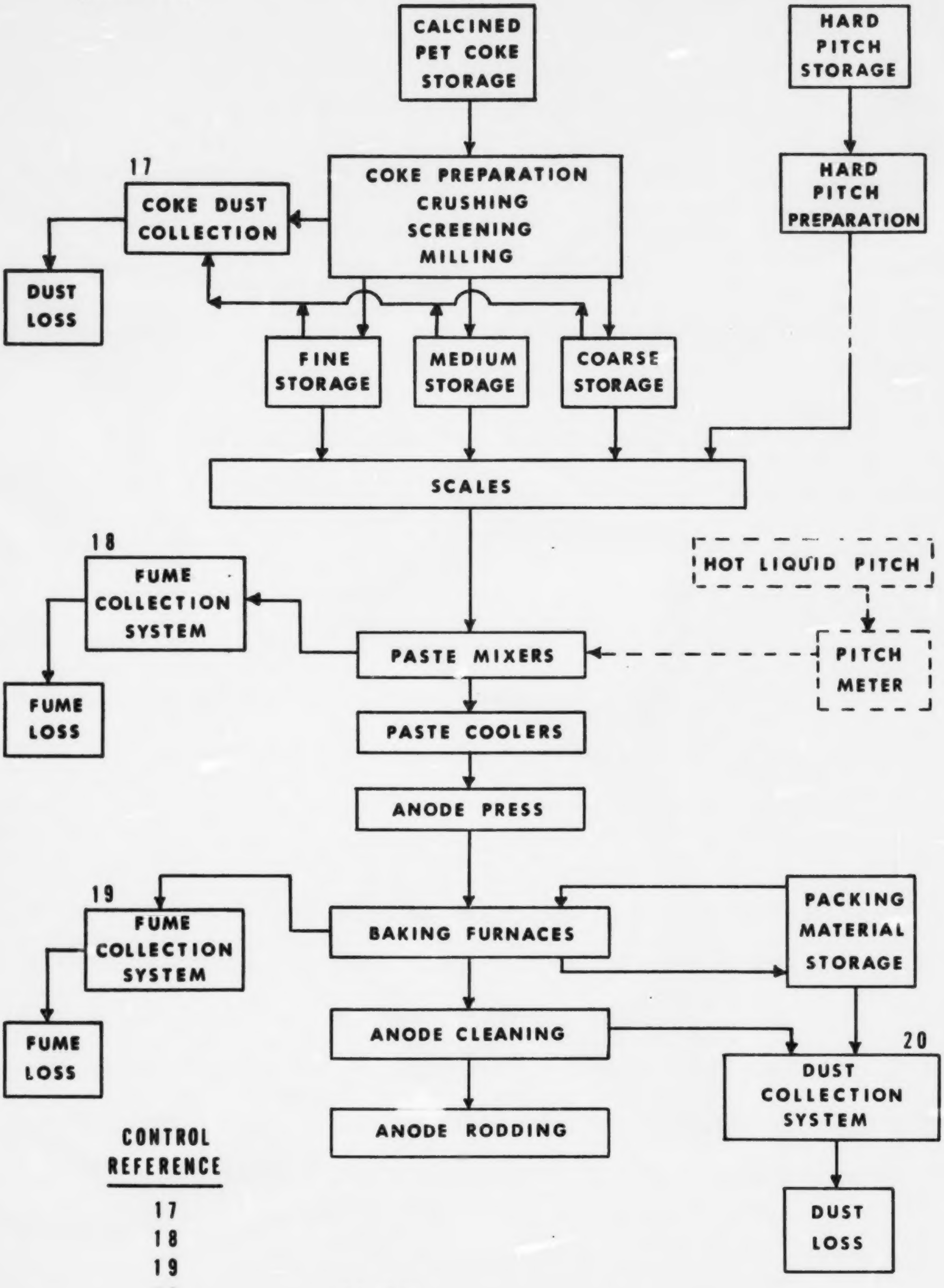
The material handling system is defined as the equipment sequences used to transport materials to and from the areas bounded by the gross perimeters of the carbon anode-prebake operations. Excluded are products transfers between the green mill and baking areas.

Separate and common collection and control systems serving material handling transfer points are individually treated in data sheets provided for their descriptions. A supplementary descriptive line flow diagram showing control references for each materials handling system, as illustrated in Fig. 2, is suggested for identification and clarification.

FIGURE 2

CARBON ANODE PREBAKE
(EXAMPLE)

PROCESS CODE: 2.20


CALCINED PET COKE STORAGE
HARD PITCH STORAGE
17
COKE DUST COLLECTION
COKE PREPARATION CRUSHING SCREENING MILLING
HARD PITCH PREPARATION
DUST LOSS
FINE STORAGE
MEDIUM STORAGE
COARSE STORAGE
SCALES
18
FUME COLLECTION SYSTEM
HOT LIQUID PITCH
PASTE MIXERS
PITCH METER
FUME LOSS
PASTE COOLERS
ANODE PRESS
19
FUME COLLECTION SYSTEM
BAKING FURNACES
PACKING MATERIAL STORAGE
FUME LOSS
ANODE CLEANING
20
DUST COLLECTION SYSTEM
ANODE RODDING
CONTROL REFERENCE
17
18
19
20
DUST LOSS

Plant Identification ______
Process Code 2.20   Prebake Anodes

5.0 Material Handling (cont'd)

For each material used in your plant in this process area please use a separate sheet of form 2.20-2 and indicate the material type, handling methods, and effluent control systems involved.

You are requested to complete these data sheets as completely as possible, indicating where data is not available, if necessary.

Plant Identification ____ Form ______-2 ___of ___
Process Code ______ Name __________ Materials Handling Transfer

Materials Handling Effluent Points

Name of Material __________________ %F __________________

Material Form Bulk ___ Pieces____
Bagged ___ Liquid____
Pallets ___ Other ____ Specify _______________

*Control Reference	Handling Method	Control Code
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX
		3.__.X.XX

Remarks:

*Please identify by number on a block flow diagram.

Plant Identification ____
Process Code 2.20 Prebake Anodes

6.0 Process Effluent and Emission Parameters

The intent of this section is to obtain a full description of the effluents generated in the green mill and baking operations, as distinguished from materials handling, of the effluent collection and control systems, and of the efficiency of these systems and their costs.

Under the section 2.0 "Physical Parameters - Plant Section" you were asked to reference code the collection control systems by building and unit operation.

Please enter these codes again on forms 2.20-3, -4, and -5.

Use as many forms as are necessary to describe the different effluent control systems used in conjunction with the unit operations of your prebake carbon anode plant, following the instructions given under section 6.0 of the potlines (2.10)

If ultimate discharge is from a stack, please complete the following information.

Stack Height, ft ____
Exit gas velocity, ft/min ____
Exit gas temperature, °F ____
Installed cost of stack, $ ____
Year built ____

Plant Identification ____
Process Code ____________ Name ___________

Form ______-3; __of__
Control System Input

Effluent Entering Control System

Control System Identification, Stage, and Type 3.__.__.__.__
(Report data common to identical systems on one sheet and list code numbers of identical systems.)

Effluent Parameter	Units	Range		Average
Temperature,				
Gas Flow Rate,	scfm			
Nitrogen concentration,				
Oxygen concentration,				
Carbon Dioxide,				
Carbon Monoxide,				
Sulfur Dioxide,				
Sulfur Trioxide,				
Fluoride as F,				
Hydrocarbons,				
Pitch condensible at 32°F				
Total Particulates,				

Particulate Composition, w%
- Alumina ______
- Fluoride as F ______
- Carbon ______
- SO_3 ______

Size Distribution w%
- $< 5\ \mu$ ______
- $< 10\ \mu$ ______
- $< 40\ \mu$ ______
- $< 100\ \mu$ ______
- $> 100\ \mu$ ______

Other identical control systems ________________________________

Remarks:

Plant Identification ____ Form _______-4; __of___
Process Code ______ Name _____________ Control System Emission

Emission from Last Stage of Control

Control System Identification Stage and Type 1/ 3.__._.__.

Effluent Parameter	Units	Range		Average
Temperature,	_____	_____	_____	________
Gas Flow Rate,	scfm	_____	_____	________
Nitrogen concentration,	_____	_____	_____	________
Oxygen concentration,	_____	_____	_____	________
Carbon Dioxide,	_____	_____	_____	________
Sulfur Dioxide,	_____	_____	_____	________
Sulfur Trioxide,	_____	_____	_____	________
Fluoride as F,	_____	_____	_____	________
Hydrocarbons,	_____	_____	_____	________
Pitch condensible at 32°F	_____	_____	_____	________
Total Particulates,	_____	_____	_____	________

Particulate Composition, w%		Size Distribution, w%	
Alumina	________	$< 5\ \mu$	________
Fluoride as F	________	$< 10\ \mu$	________
Carbon	________	$< 40\ \mu$	________
SO_3	________	$< 100\ \mu$	________
		$> 100\ \mu$	________

1/ Emissions without control, such as may come from roof monitors, should be designated 3.__. 0.XX

Plant Identification_____
Process Code_____ Name ________

Form _____-5__ of__
Control Equipment

Operating Parameters and Costs for

Effluent Control Equipment

Control Unit Code Number: 3.__._.__

Number of identical units in parallel at this stage_______

Manufacturer ____________________

Catalog number or other description ___________________________

	Total Gas Flow:	Actual cfm	Pressure Drop, in. H_2O
	min	__________	____________
	max	__________	____________
	AVg	__________	____________

Total Fans: Number _____ cfm _____ HP _______

Liquor Flow, gpm _______ Composition of Solvent __________

F concentration in discharge from control system, ___________

Disposition of separated HF,____________________________________

Total Pumps: Number _____ gpm _____ psi _____ HP ____________

Total Particulates Separated, ______________________lb/hr.
Identification ____________________________
Destination: Discard _____, Recycle _____, where? _________

Value of recovered fluorine, $_____per ton of separated F.

*Installed Cost of Collection Equipment, hoods, enclosures.
ductwork, etc. $ ____________Year installed ____________.

*Installed Cost of Removal Equipment, $ ___________Year_______.

Annual Operating Costs:
Power, $ ______________ Chemicals $_______________ Parts $ _______

Operating labor $___________________Maintenance labor $___________.

*Installed costs include purchase costs of all fans, pumps, drivers, piping, structurals, ductwork, electrical accessories, instrumentation, etc., installation labor costs, and engineering costs paid directly by the smelter operator. Costs of collection and removal equipment are additive to represent total costs of control systems.

Appendix 4A

Particle Size Weight Distribution

Figures 4A-1 through 4A-7 present data from ten particle size vs weight fraction determinations on several kinds of reduction plant effluents, derived from aluminum industry sources.

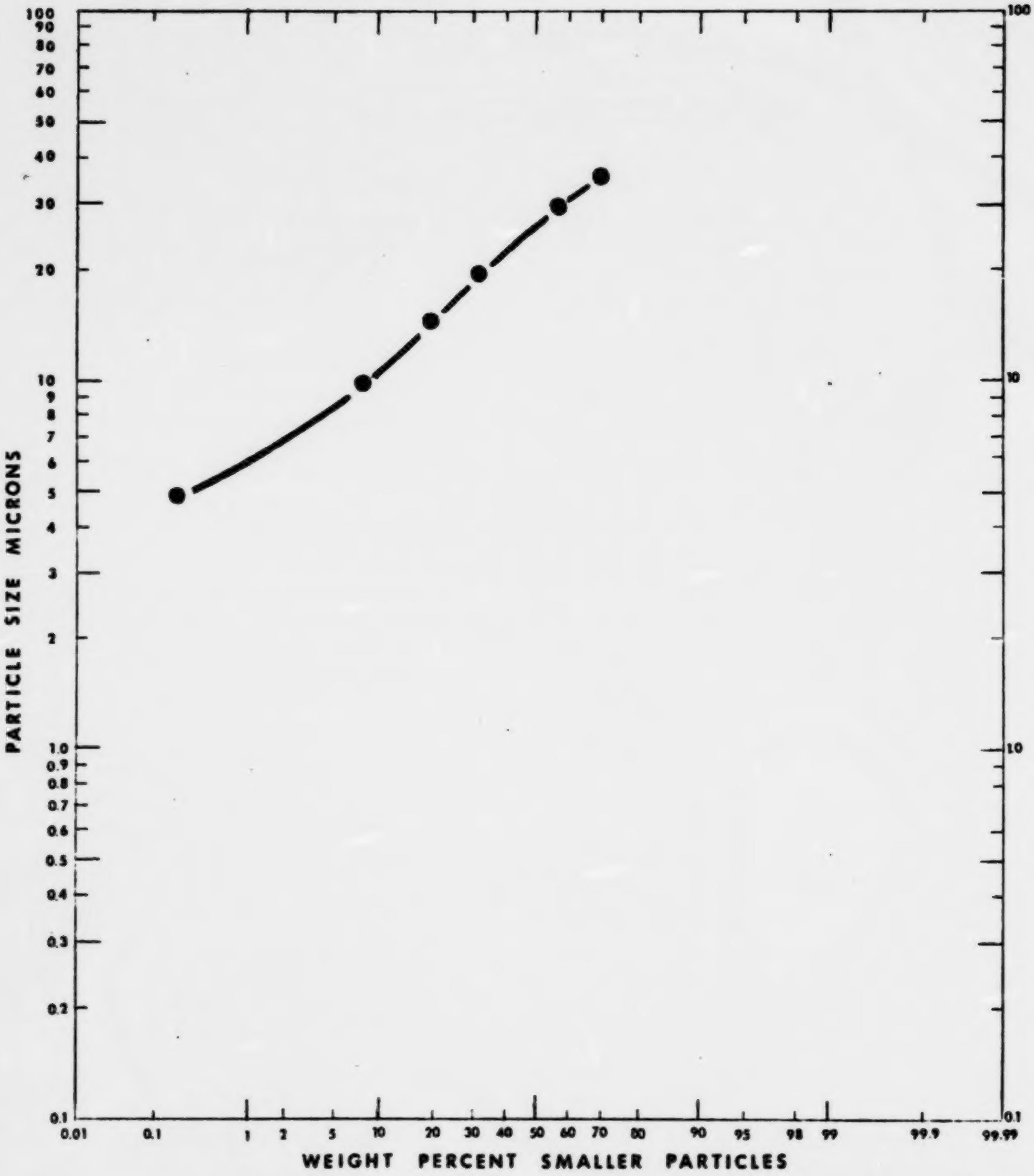
The determination of aerodynamic particle size distribution is inexact at best and these data should be interpreted as indications of the difficulty with which the dusts might be captured by removal equipment rather than as precisely known characteristics of the several dusts. If the size distribution of a dust is determined by the same techniques used to measure the fractional removal efficiency of a control device, the two data may be combined to estimate the total removal efficiency for the device when working on the subject dust. Details as to how the following data were obtained are lacking.

FIGURE 4A-1

PARTICLE SIZE WEIGHT DISTRIBUTION

PREBAKE PRIMARY EFFLUENT

MULTIPLE CYCLONE CATCH



SOURCE - INDUSTRY DATA

FIGURE 4A-2
PARTICLE SIZE WEIGHT DISTRIBUTION
PREBAKE POTROOM DUST
(NO PRIMARY COLLECTION)

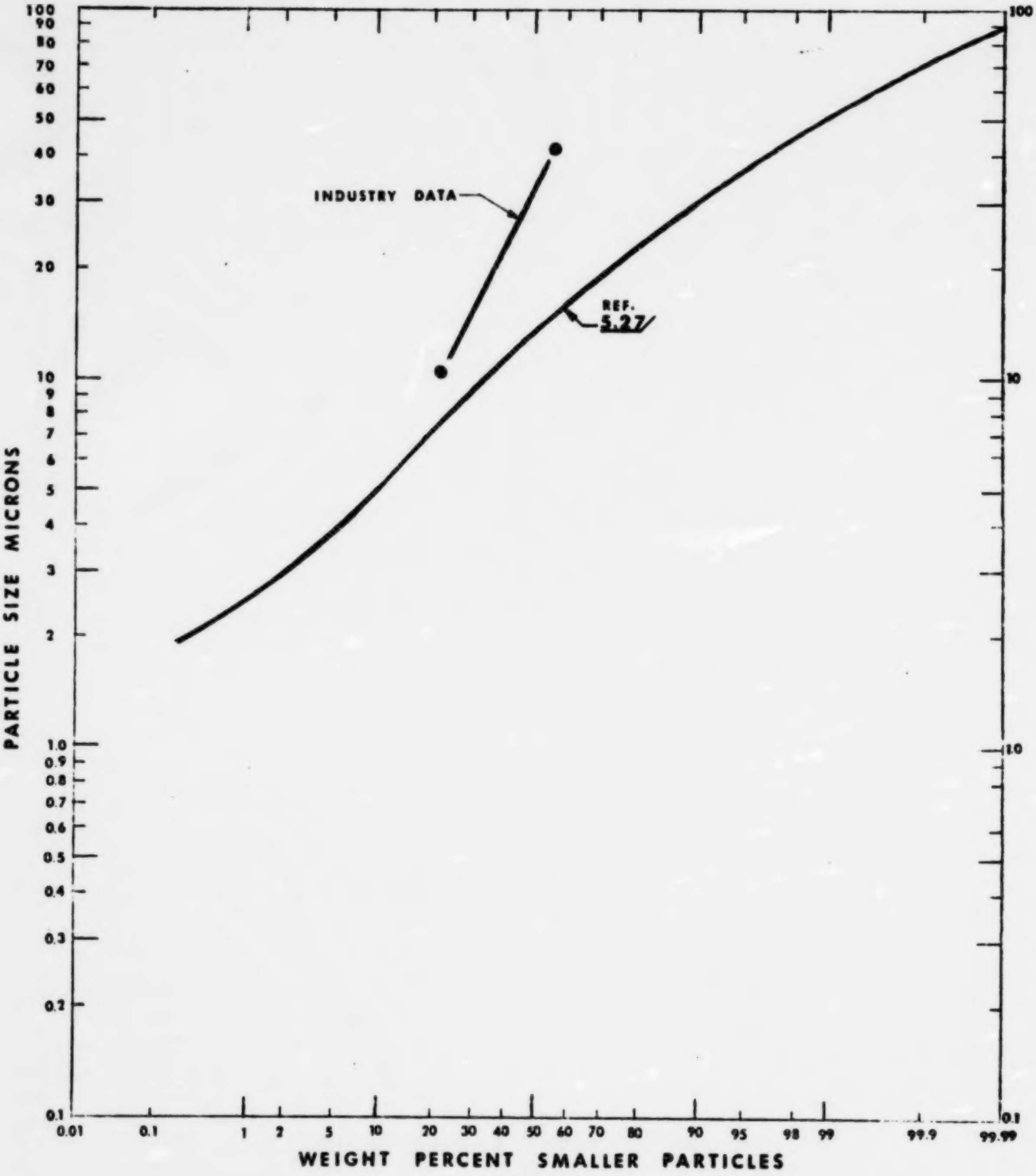
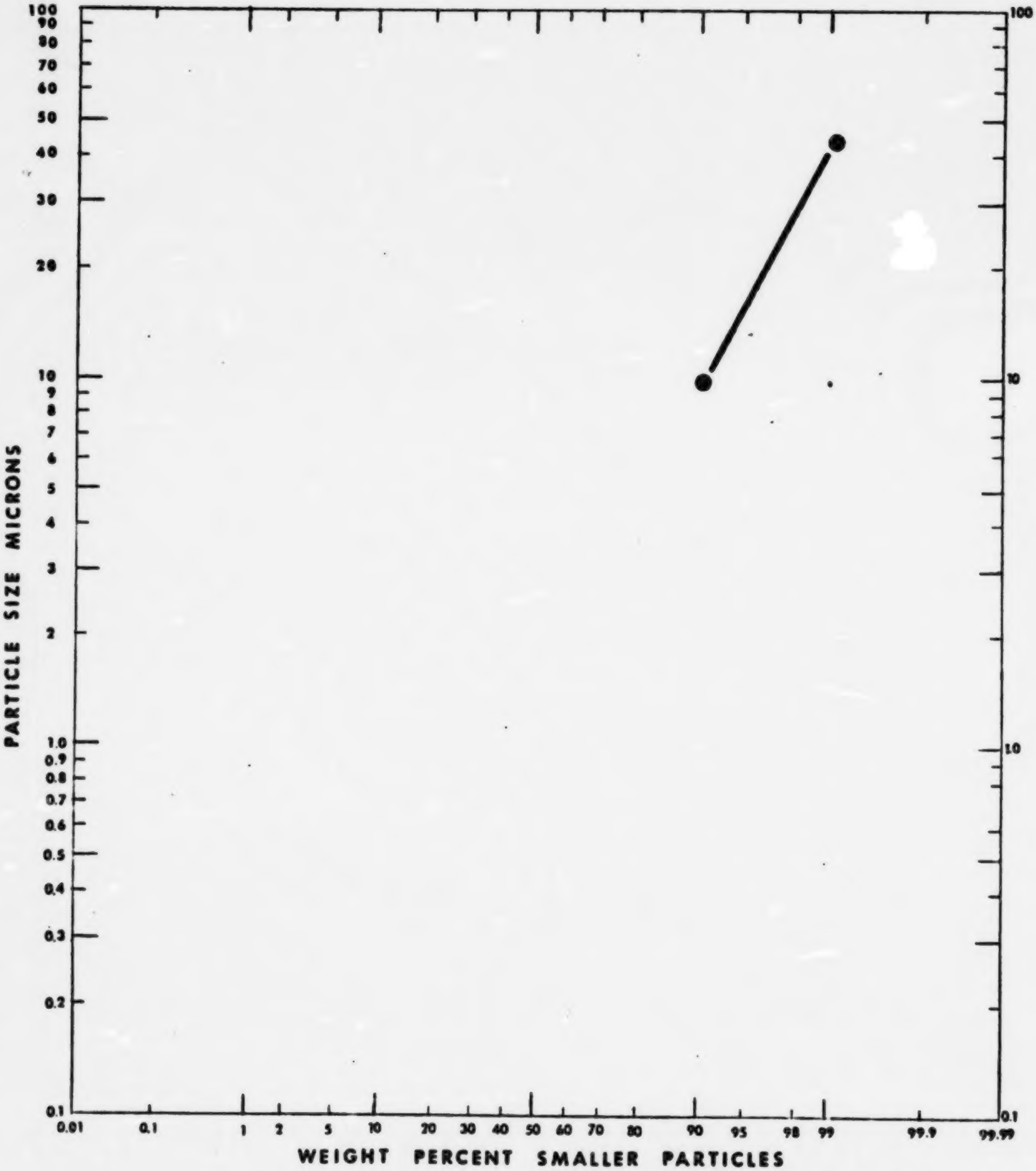


FIGURE 4A-3

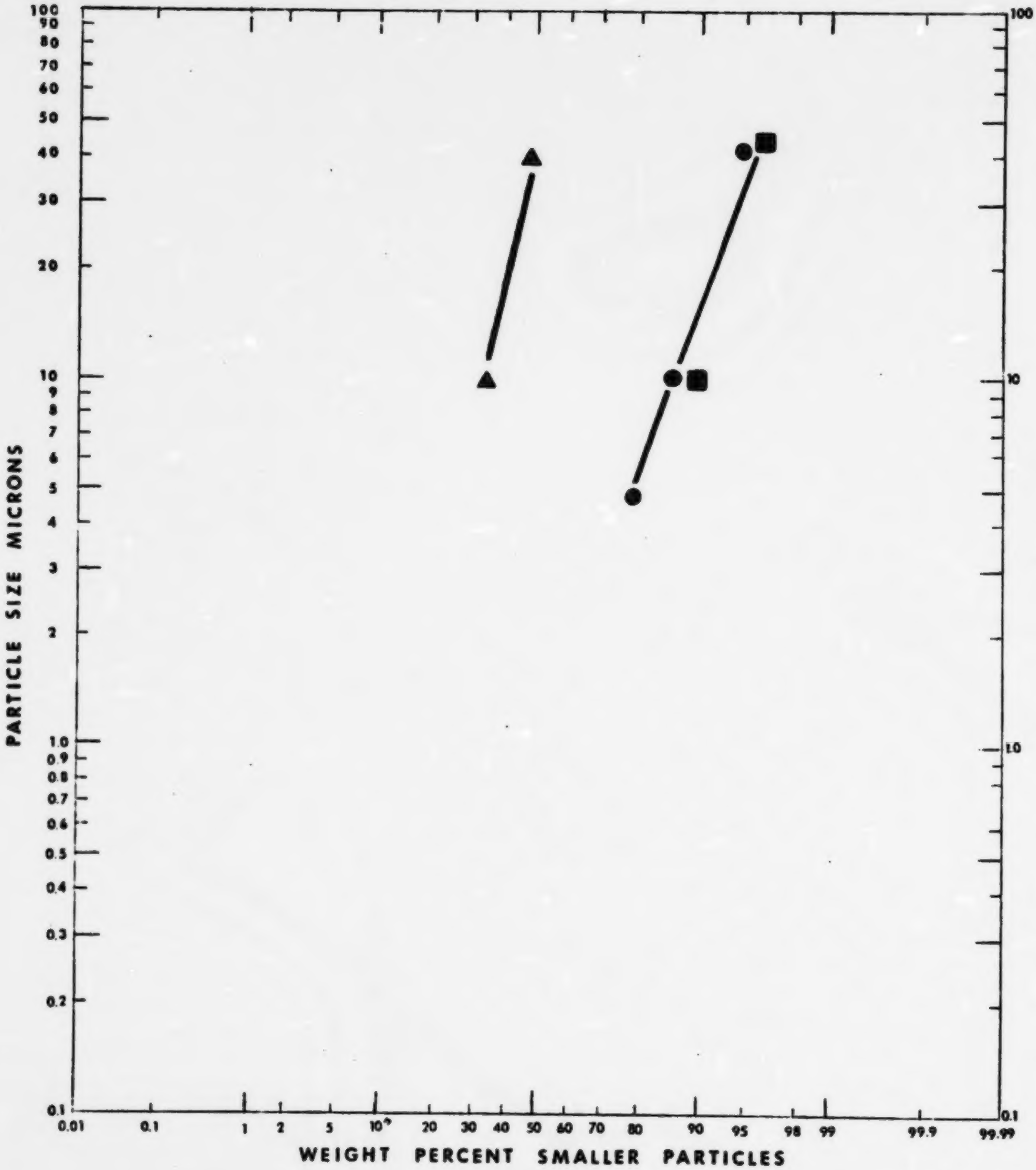
PARTICLE SIZE WEIGHT DISTRIBUTION

ANODE PASTE MIXING FUME



SOURCE - INDUSTRY DATA

FIGURE 4A-4
PARTICLE SIZE WEIGHT DISTRIBUTION
BAKE FURNACE EFFLUENT
(THREE INSTALLATIONS)

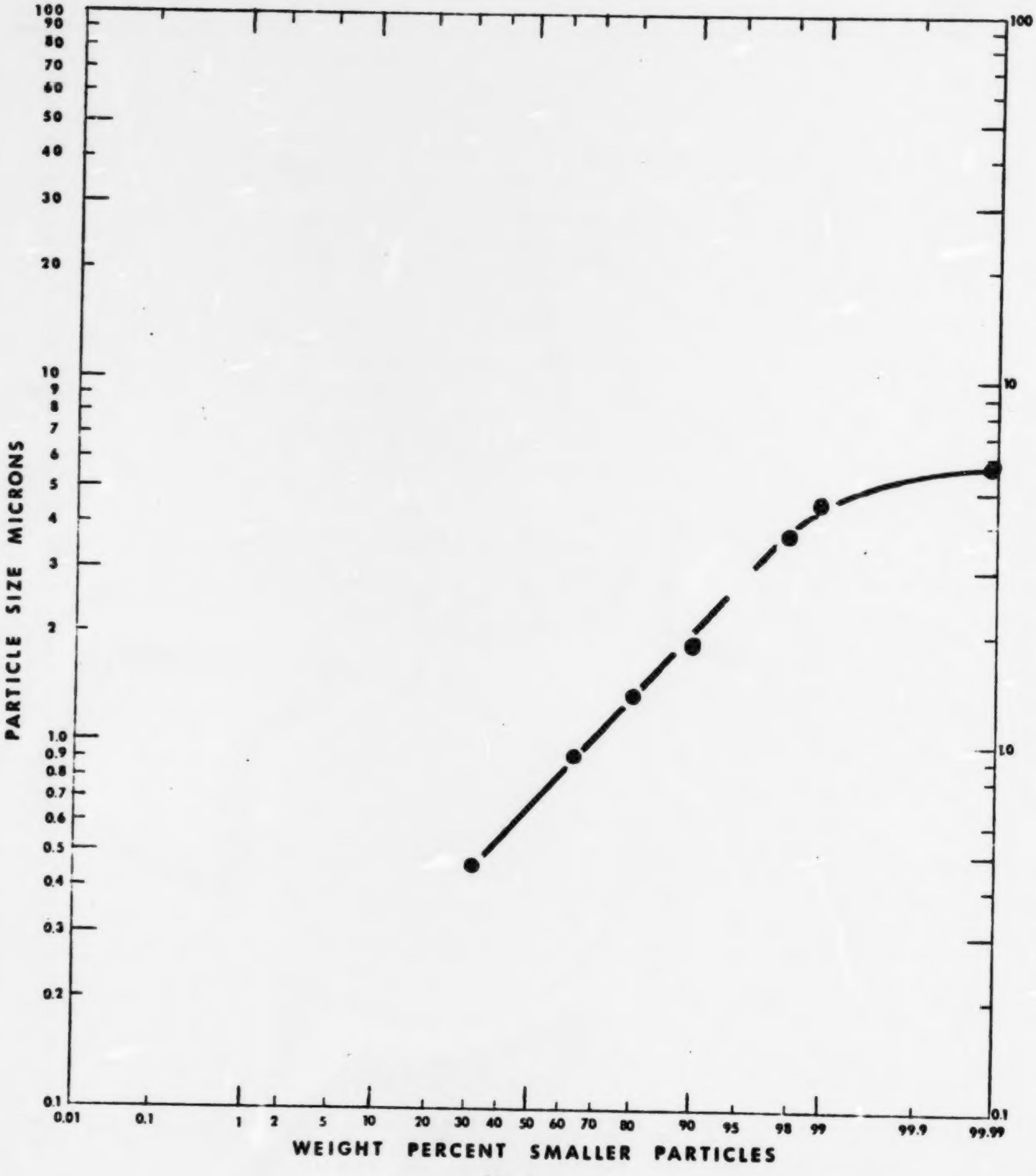


SOURCE - INDUSTRY DATA

FIGURE 4A-5

PARTICLE SIZE WEIGHT DISTRIBUTION

CAST HOUSE EFFLUENT



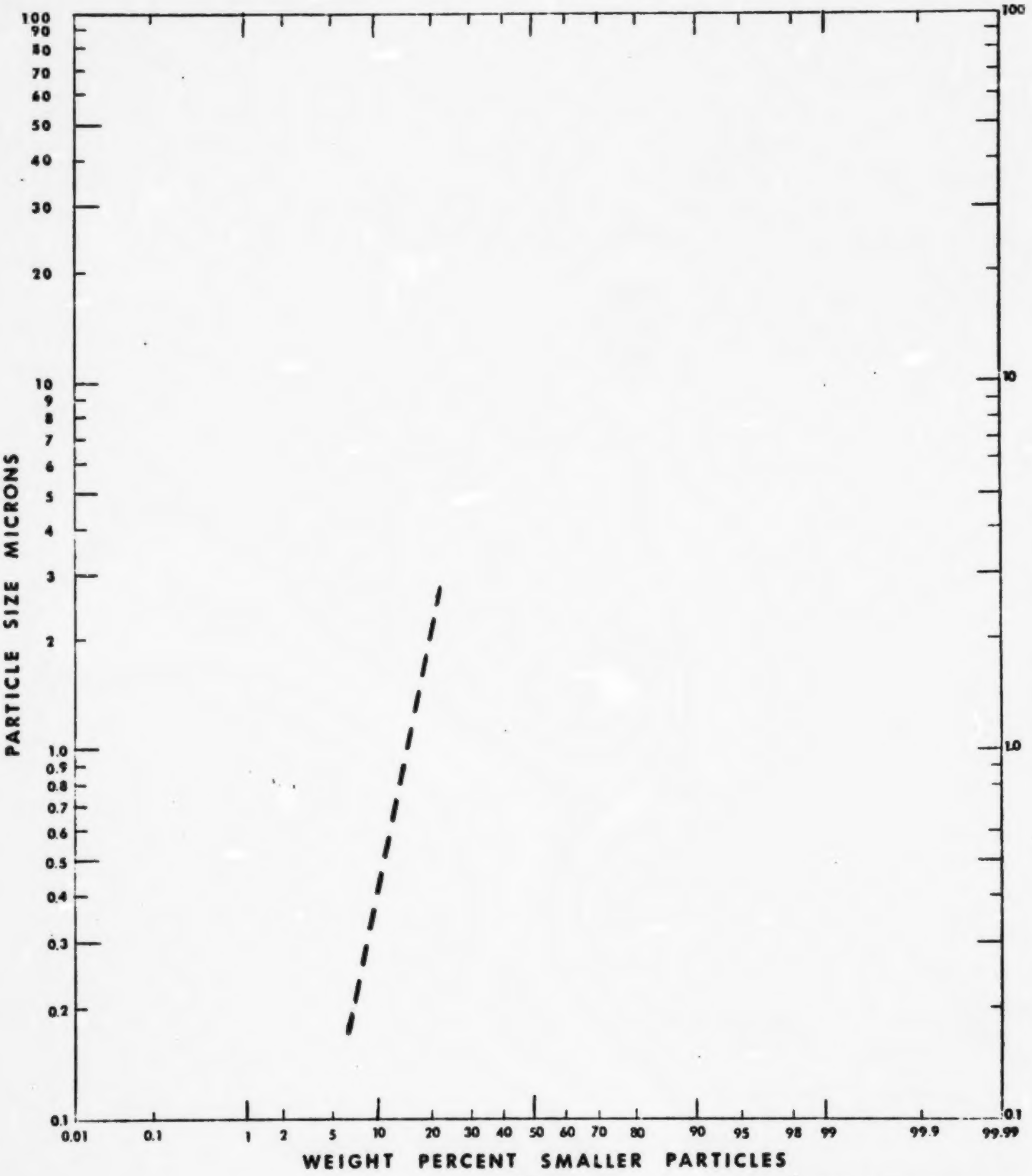
SOURCE - INDUSTRY DATA

FIGURE 4A-6

PARTICLE SIZE WEIGHT DISTRIBUTION

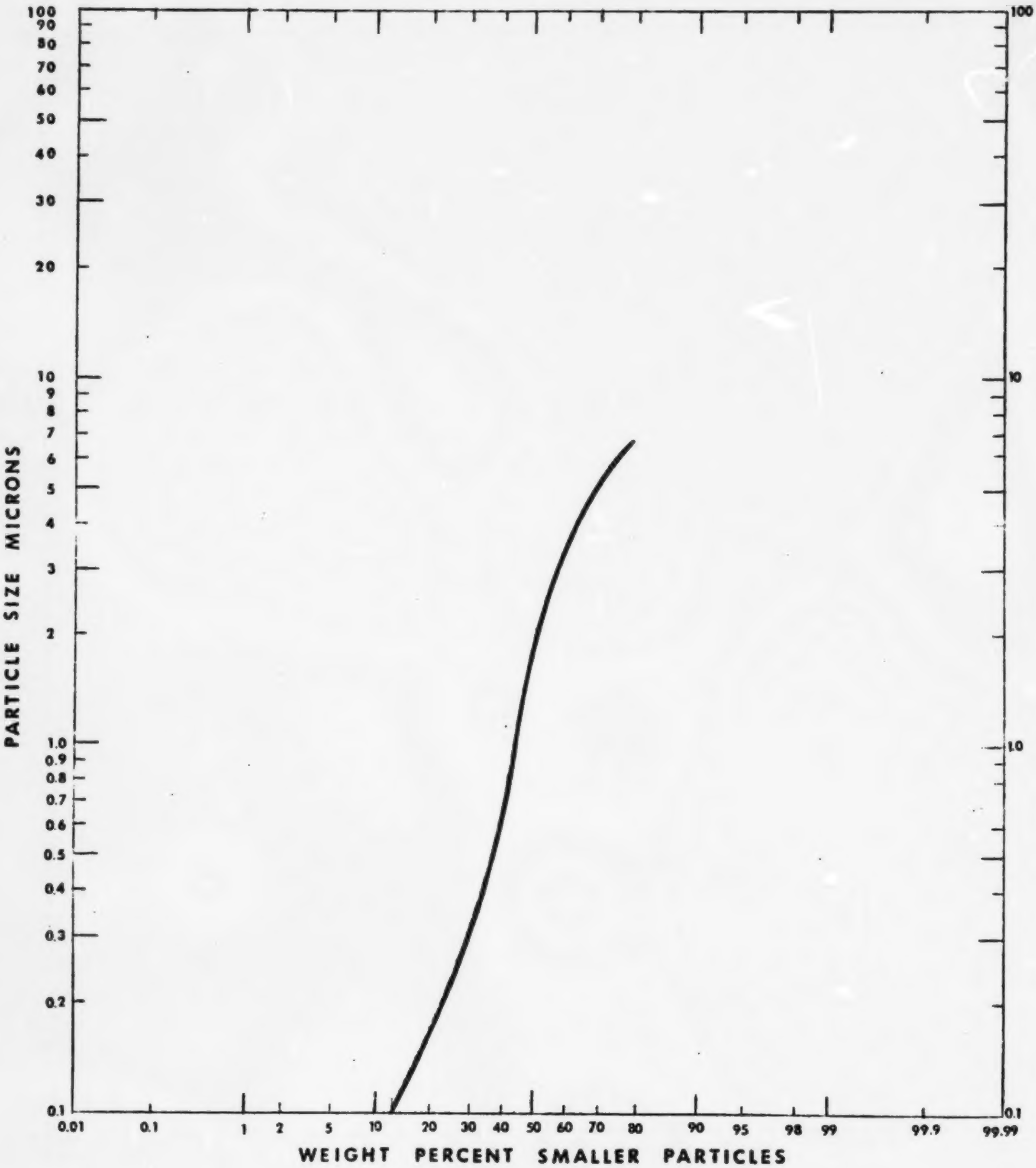
EFFLUENT FROM SKIM RECLAMATION

ROTARY BARREL



SOURCE INDUSTRY DATA

FIGURE 4A-7
PARTICLE SIZE WEIGHT DISTRIBUTION
PREBAKE SECONDARY EFFLUENT



SOURCE INDUSTRY DATA

Appendix 5A

Fractional Removal Efficiency Curves

The performance of particulate removal equipment can be described by a fractional removal efficiency curve, a plot of a device's removal efficiency versus particle size for a given set of operating parameters. The fractional efficiency curve for a piece of equipment and the weight distribution of particle sizes in an effluent dust, measured with the same techniques, may be combined to estimate the overall removal efficiency.

The following curves are presented:

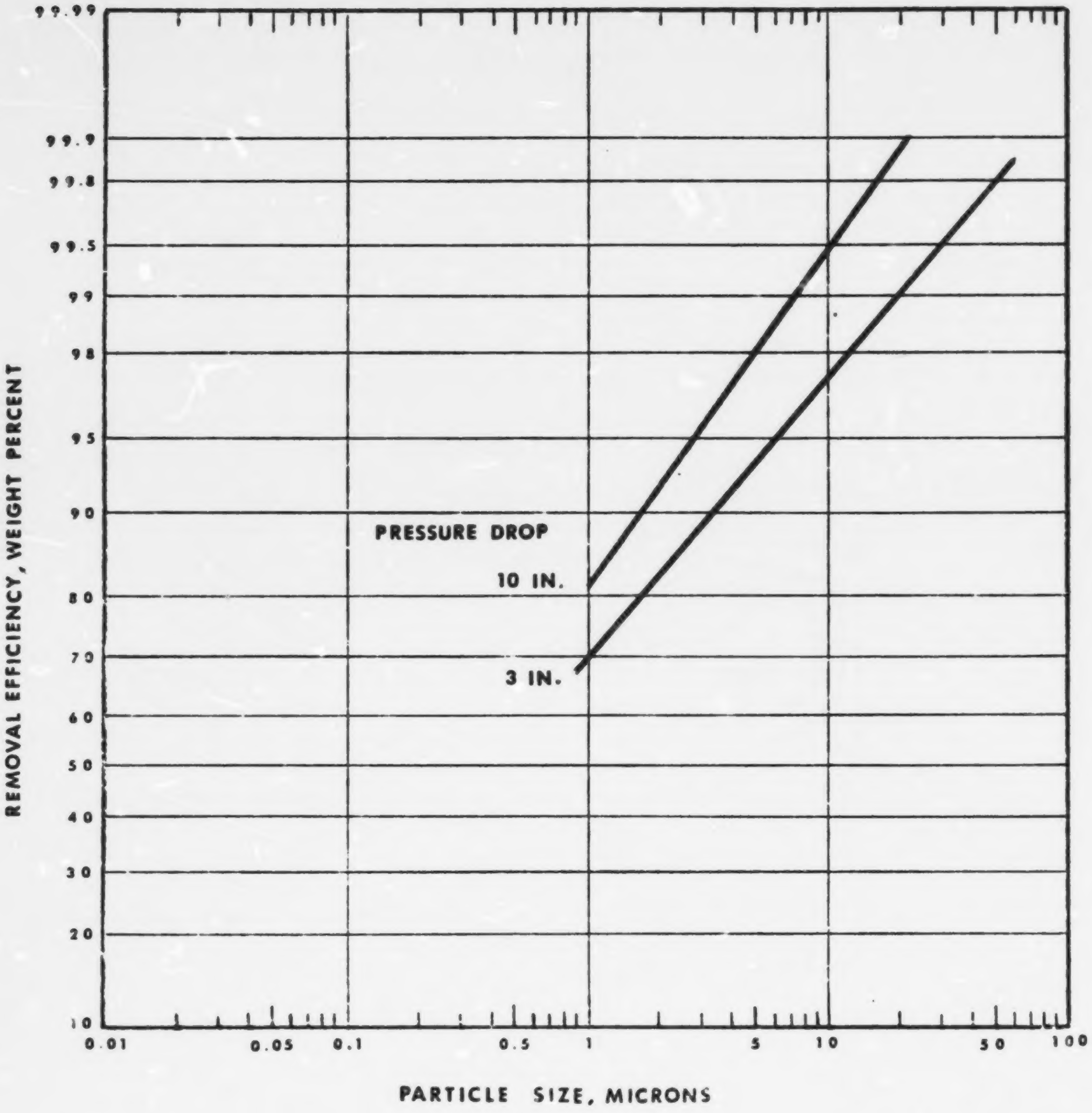
5A-1 Self-Induced Spray operating at 3 in. and 10 in. water gage pressure drop. Curve was supplied by Western Precipitator Division, Joy Manufacturing Company.

5A-2 Venturi Scrubber from Dickie, L. "Air Pollution Control Equipment Operation, Application, Cost, and Effectiveness". Presented at a meeting of N.Y.A.S.H.R.A.E., October, 1969.

5A-3 Centrifugal Wet Scrubber. Data received from Vibro Dynamics Company.

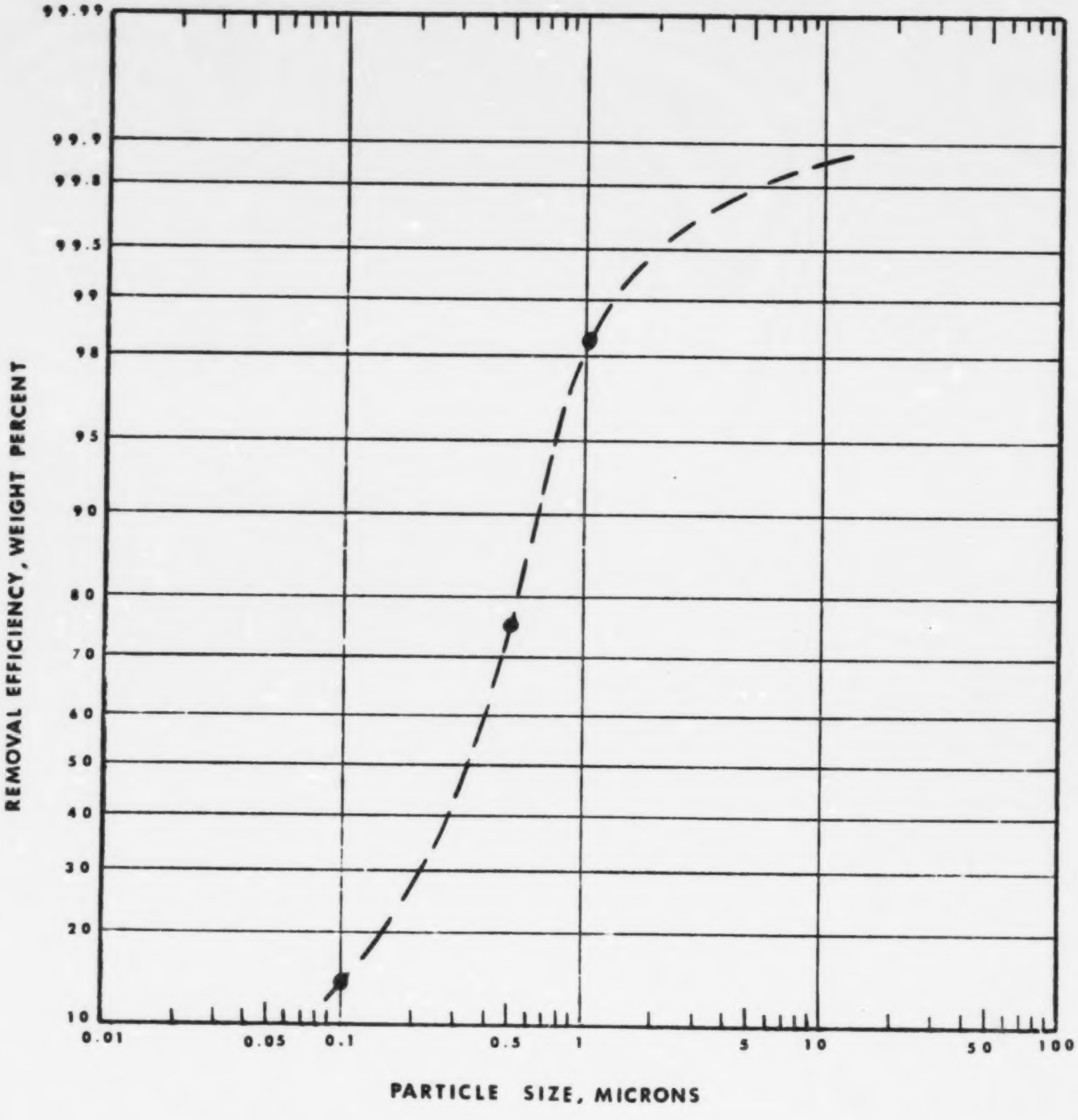
5A-4 Wet Impingement Scrubber curve taken from Stairmand, C.J. "The Design of Modern Gas Cleaning Equipment", Jour. Inst. Fuel, London (February 1956).

FIGURE 5A-1
FRACTIONAL REMOVAL EFFICIENCY
ORIFICE TYPE SCRUBBER



Source: Joy Manufacturing Co.

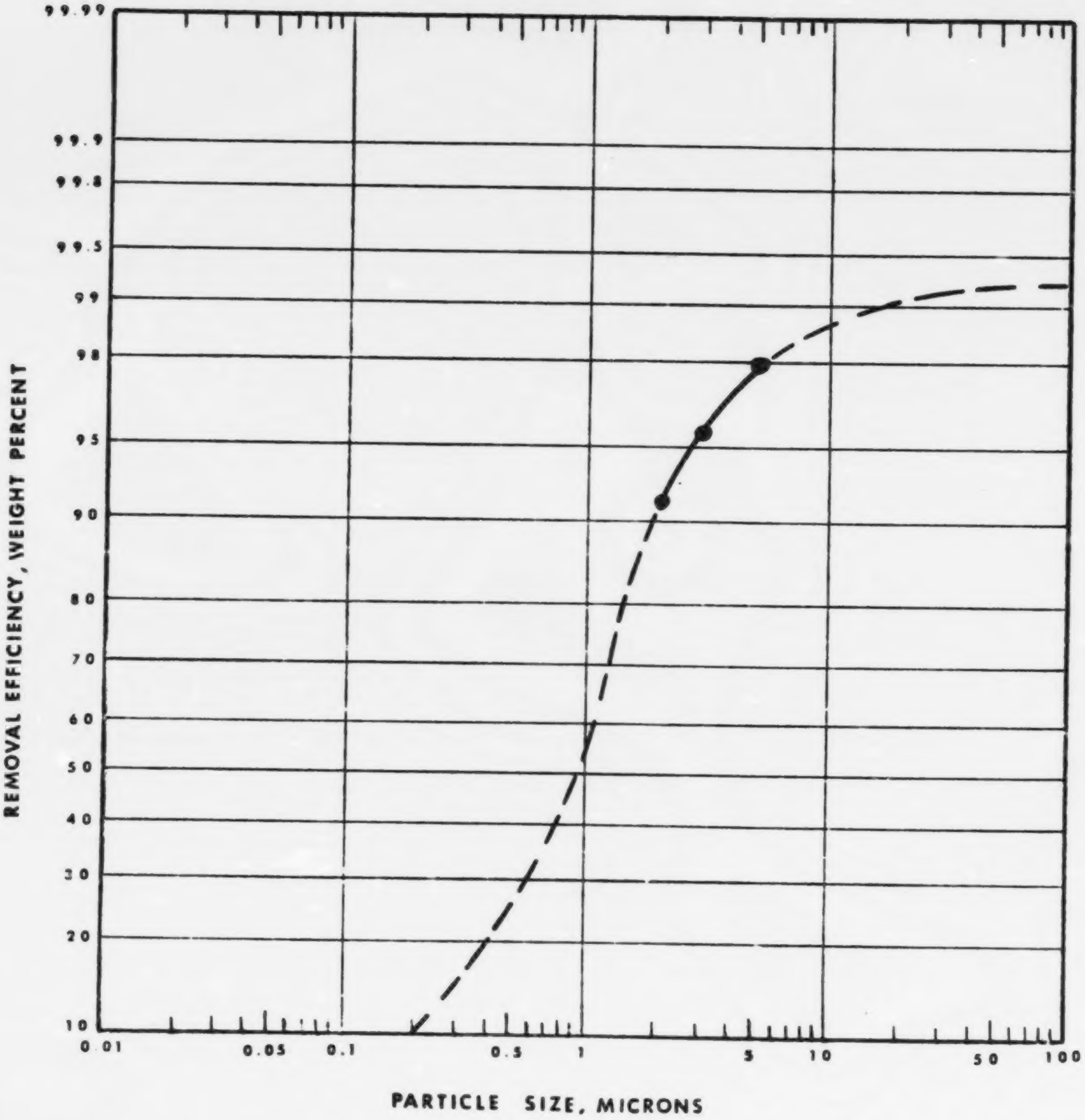
FIGURE 5A-2
FRACTIONAL REMOVAL EFFICIENCY
VENTURI SCRUBBER



Source: L. Dickie

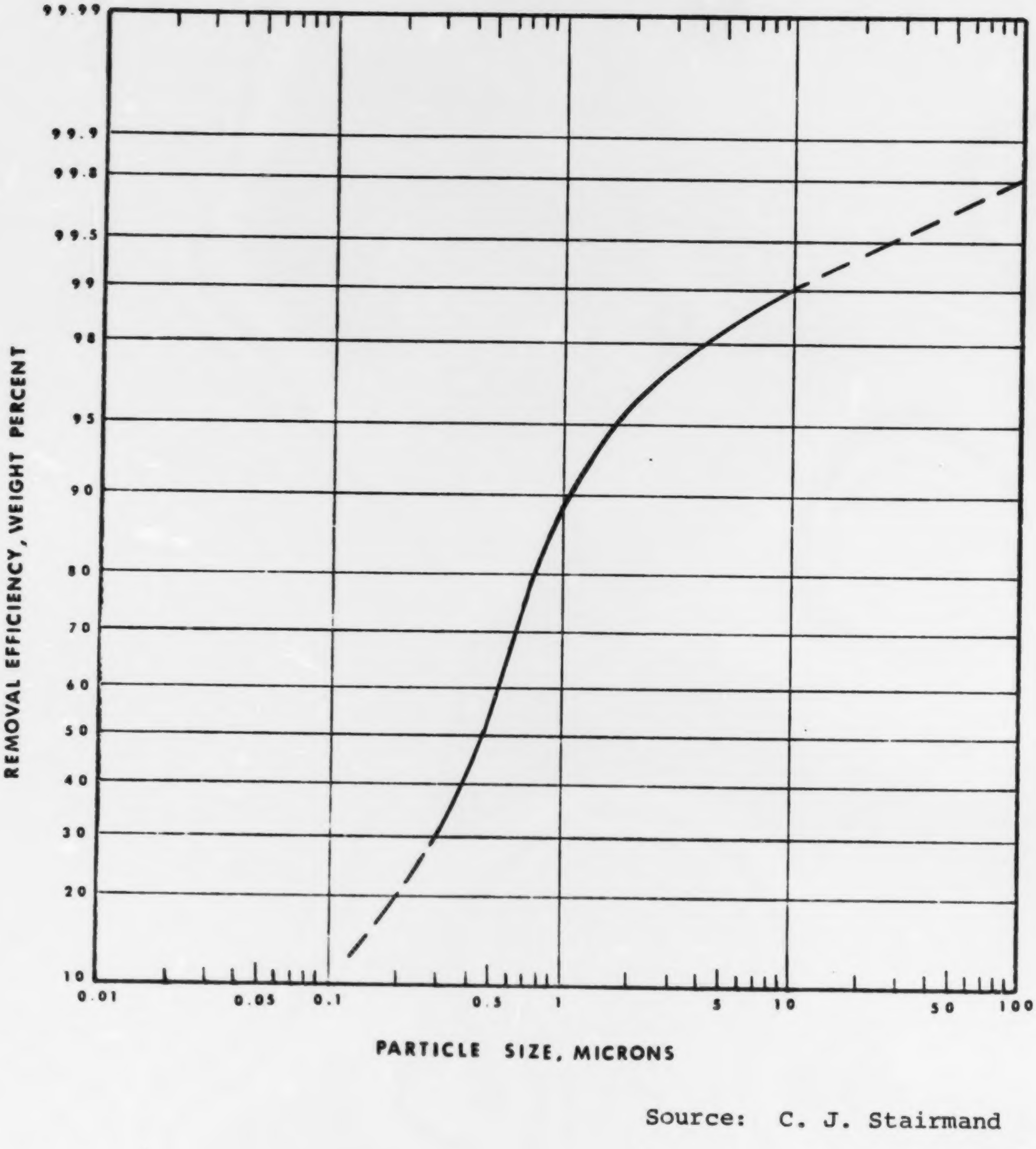
FIGURE 5A-3

FRACTIONAL REMOVAL EFFICIENCY CENTRIFUGAL WET SCRUBBER



Source: Vibro Dynamics Co.

FIGURE 5A-4
FRACTIONAL REMOVAL EFFICIENCY WET IMPINGEMENT SCRUBBER TOWER



Source: C. J. Stairmand

Appendix 6A

Pollutant Sampling and Analysis Techniques

6A.1 Procedures Reported

Several aluminum producers have supplied descriptions of procedures followed in obtaining representative samples of potline effluents and in analyzing the samples for particulates, soluble solid fluoride, insoluble solid fluoride, gaseous fluoride, tars, and sulfur oxides.

Although similar, the sampling and analytical procedures differ in details of equipment and method developed by the individual organizations to meet their specific needs. It is beyond the scope of this study to evaluate one procedure with respect to another or to critically assess the applications. They are presented in this appendix as illustrative references.

6A.2 Source Scrubber Sampling and Analytical Procedures at a Prebake Reduction Plant

Velocity determinations are made at a point where the gas flow is as uniform as possible. An accurate gas flow is needed for sampling at isokinetic conditions. A standard pitot tube and differential pressure gauge are used to take a traverse across the duct. The gas temperature is measured and the pressure readings from the traverse are converted to velocity by the basic formula:

$$Vs = 3.90 \sqrt{\frac{29.92}{Ps} \times \frac{1.00}{Gd} \times HTs}$$

where

Vs is the velocity of the gas in feet per second.
Ps is the absolute pressure of the gas in inches of mercury in the duct.
Gd is the specific gravity of the gas referred to air.
H is the gauge readings in inches of water.
Ts is the absolute temperature of the gas (degrees C + 273).

The gas sample is drawn through a sampling train consisting of a sample probe, an alundum or paper filter, a membrane back-up filter, an impinger train consisting of one impinger filled with 200 mls of 1N NaOH solution for removal of gaseous fluorides and one impinger filled with 200 grams of silica gel for water removal, a gas flow meter, a vacuum pump, and a dry gas meter. The samples are taken from the inlet and outlet ducts of the scrubber simultaneously at isokinetic rates. Sampling time is a minimum of three hours.

The sampling train for the electrostatic precipitators is the same except a glass probe packed with fiber glass followed by a membrane back-up filter is used to collect tars and particulates.

The collected samples are carefully transported to the chemical laboratory for analysis. The filters are dried, desiccated and weighed to the nearest 0.1 mg on an analytical balance and the original weights of the filters are subtracted, thus yielding the total weights of the particulates collected. To determine the particulate fluoride, the fluoride in the filters is fixed with CaO, then fused with NaOH and finally the fluoride content is determined by the "Semi-Automated Method for the Determination of Fluoride" using a Technicon Auto-Analyzer. The gaseous fluoride collected in the impinger bottle containing NaOH solution is determined by either the "Semi-Automated Method" or by use of a fluoride "specific ion" electrode.

The total volume of air sampled is converted to standard conditions and is divided into the weights of particulate fluoride and HF gas as determined above in order to report the analytical results as milligrams of constituent per standard cubic foot of gas.

6A.3 Source Sampling Procedure for a Prebake Potline Using Dry Scrubbers

Sampling is carried out isokinetically in the inlet duct and/or outlet stack. It may be done either at a single, average-velocity point, as determined by a preliminary pitot-tube traverse, or by continuous traverse, depending upon the purpose of the test. The sampling train consists of the following parts:

a) Entry Nozzle, L-shaped. Aluminum tubes of 1/4" or 3/8" I.D., 4" total length, bent in a smooth curve of about 1-1/2" radius. Entry is tapered to a sharp edge and the tube is coated (internally) with epoxy enamel.

b) Thimble Holder, Alcoa design. Similar to Western Precipitation Corporation's paper thimble holder, cat. no. D1012, and internally coated with methyl methacrylate ("Krylon"). The Alcoa design holder accepts a 33 x 94 mm thimble (Whatman Extraction Thimble, cellulose, single thickness).

c) Connecting Pipe. Aluminum pipe (1/2" I.D. electrical conduit) of convenient length, internally coated with epoxy enamel, and attached to outlet of thimble.

d) Connecting Tubing. Viton tubing, 1/2" I.D. and of minimum length, is used to connect the sampling probe to inlet of an impinger train, and to make all connections up to the mist trap.

e) Impinger Train. Two Greenburg-Smith standard impingers, in series, each containing 125 ml of 0.1N NaOH solution. Impingers are followed by a mist trap (e.g., empty impinger, Erlenmeyer flask, or bottle).

f) Gas Metering Device. Sprague dry gas meter, or equivalent, with pressure gauge and thermometer. Must be calibrated before use.

g) Suction Source. Electrically-driven air pump or compressed air aspirator may be used, but must be of sufficient capacity to draw air at a minimum rate of 1 cfm through the assembled train.

Paper thimbles are numbered (with pencil) dried overnight at 105°C in tared weighing bottles, and cooled in a desiccator for 1 hour. The bottle stoppers are quickly replaced, and each bottle-plus-thimble is weighed. Care must be exercised in cleaning and charging collection devices in the laboratory, and in assembling trains at the sampling site. Where possible, the entire train (up to the gas meter) is assembled and sealed in the laboratory, and transported as a unit. Masking tape is a convenient sealant and should also be applied to cover ground joints of the impingers. After assembly, each train is checked for leakage by blocking the nozzle and applying about 10 in. mercury vacuum. If the vacuum holds with pump hose clamped shut, sampling may be started.

The sampling probe should be inserted in the duct with the entry nozzle looking downstream (upward, in a stack) to prevent premature entrance of particles. The sampling probe is rotated into the stream as the suction device is turned on. A similar precaution is taken at shut-down; probe is rotated 180° to prevent loss of collected solids from the entry nozzle.

Throughout the sampling period, readings of gas meter temperature, pressure drop, indicated gas volume, and rate are recorded at regular intervals. Sampling rate may require occasional adjustment as loading of the filter increases. It may be necessary to add distilled water to the first impinger during prolonged sampling; immersion of impingers in an ice bath will reduce the rate of evaporation.

On removal of the probe from the stack, the entry is again sealed with masking tape, and the probe carried to the laboratory with nozzle upward. All outer surfaces of the probe, connecting hoses, impingers, and trap are cleaned before disassembly and recovery of the sample. Solids from inside the entry nozzle are added to the thimble, which is then dried and weighed as before. Inside surfaces of thimble holder, connecting pipe, hoses, and mist trap are rinsed with distilled water and rinsings added to the combined impinger liquids.

Determined blanks are deducted from sample results: a clean thimble is dried, weighed, and analyzed in the same fashion as sample thimbles; sodium hydroxide solution and make-up water (if required), in volumes equal to those used in sampling, are also carried through the entire analytical procedure.

6A.4 Source Sampling and Analytical Procedures at a Smelter Using Secondary Control Only

Scope of Determinations

This process of analysis comprises the following directions and determinations:

6A.4.1 Principle of the "Standard" method for analyzing flue gases.

6A.4.2 Arrangement of the sampling stations.

6A.4.3 Sampling position and location of the probe aperture in the stream of gas.

6A.4.4 The selection of the type of probe according to the flue gas.

6A.4.5 Fundamentals for sampling final gases after washing installations.

6A.4.6 Choice of the diameter of the probe aperture.

6A.4.7 Directions for measuring rate of flow of gases and amounts of gas.

6A.4.8 The sampling apparatus.

6A.4.9 The preparation of the apparatus for sampling.

6A.4.10 Carrying out sampling.

6A.4.11 Dismantling and emptying the sampling apparatus.

6A.4.12 Determination of tar.

6A.4.13 Determination of dust.

6A.4.14 Determination of S (gaseous).

6.4.15 Determination of F content.

6.4.16 Processing the contents of the droplet separating bottle.

6A.4.1 Principle of the "Standard" Method for Analyzing Flue Gases

a) Sampling

The gas to be analyzed is taken from the stream of gas by means of a probe adapted to the nature of the flue gas. The solid constituents, dust and tar, are separated in a heated filtering apparatus, the temperature of which is kept at 85°C by means of a thermostat, by filtering the gas to be analyzed through a filter thimble. The heating of the filtering apparatus serves to evaporate any droplets of spray water which may be present, so as thereby to avoid any absorption of gaseous HF in the filter thimble.

The gaseous constituents, HF and SO_2, are absorbed in three absorption washing bottles connected in series, which are filled with glass beads. Five percent soda solution is used as absorption solution. The washing bottles and accessories are combined in an absorption apparatus.

The suction pump and the gas-measuring equipment are combined in a separate pump station.

b) Working up the Sample in the Analytical Laboratory

The filter thimbles are extracted with "tri" in a Soxhlett apparatus to separate the tar.

After the "tri" has been distilled off, the flasks are dried at 80°C and the tar content is weighed out.

The filter thimbles are dried at 105°C and the dust content is weighed out.

The dust in the filter sleeves is washed with H_2O; by determining the fluorine in the solution (distillation and titration), the content of water-soluble fluorine is obtained. The dust is thereafter boiled out with 5% NaOH; by determining the fluorine in the solution, the content of insoluble fluorine in the dust is obtained.

The gaseous fluorine in the absorption solutions is obtained by determination (F determination - distillation and titration with $Th(NO_3)_4$). The gaseous S is obtained by precipitating it gravimetrically with $BaCl_2$ as $BaSO_4$.

6A.4.2 Arrangement of the Sampling Stations

The sampling stations must be accessible without danger. Steps must be taken to see that the sampling apparatus can be fixed or set up without any difficulty. It should be possible to fit up the connections to the pump station (suction pipe, electric cables) without any great expenditure of work, or permanent installations should be arranged.

Measuring flanges (for sampling and measuring the amounts of gas) having an inside diameter of at least 100 mm are to be installed in pipe lines and flues at the sampling stations.

Pipe lines should have as large a cross-section as possible at the sampling station so that the gas velocities become as small as possible. Wide probe apertures can then be used, whereby the danger of blocking thereof is reduced and also the aerodynamic conditions for satisfactory sampling are improved. There should be no bends and inlets in the pipe line for a distance of five times the diameter in front of the sampling station.

If the speed of flow exceeds 8 m/s, special measuring sections are to be installed in the pipe line. The following table contains the dimensions of the measuring sections, calculated for a speed of the gas of 7.5 m/s. These dimensions permit the use of probe apertures with a diameter of 4.0-4.5 mm.

Volume of Gas	Pipe Diameter	Length of Measuring Section
0.2 cu.m/s	20 cm	2.0 m
0.5 cu.m/s	30 cm	3.0 m
1.0 cu.m/s	40 cm	4.0 m
2.0 cu.m/s	60 cm	6.0 m
3.0 cu.m/s	70 cm	7.0 m
4.0 cu.m/s	80 cm	8.0 m
5.0 cu.m/s	90 cm	9.0 m

6A.4.3 Sampling Position and Location of the Probe Aperture in the Stream of Gas

In crude gas lines of Soderberg S4 and VS8 installations the sampling stations are installed in front of the cyclones and in front of the washing apparatus.

In waste-gas chimneys of Soderberg installations, the sampling station should, if possible, be located 1 - 3 meters below the mouth. Where conditions are unfavorable, the sampling may also be carried out at the foot of the chimney (at a height above the inlet corresponding to five times the diameter), provided that there are no spray nozzles above the sampling station. The droplet separating bottle connected to the outlet end of the probe simulates the processes taking place in the chimney.

In sampling in waste-air chimneys of shop spray plants having a rectangular cross-section, the probe is located in the central axis. If possible, the probe should be shifted twice a day along this axis, so that the entire length of the spray field is covered during the sampling period.

In shop air final gas analyses, care should moreover be taken that no air infiltrates from the atmosphere into the probe aperture. To this end, the probe is introduced into a sheet-metal jacket through a slot therein. The jacket has a diameter of 40 cm and a height of 50 cm, and is placed directly on the droplet-collecting layer (brushwood or p.v.c. mesh). The probe aperture should be located about 15 cm above the droplet-collecting layer.

In sampling from pipe lines, the probe aperture should be arranged as far as possible towards the center of the pipe.

The general rule is that the probe aperture must always be directed against the stream of gas.

6A.4.4 The Selection of the Type of Probe According to the (Furnace) Flue Gas

a) Shop Air Before Reaching the Roof Spray Plant

The rate of flow is small; the gas for analysis only contains the finest of particles in the form of an aerosol; the moisture content is low.

A simple probe consisting of a tube with an internal diameter of 8 - 9 mm bent at right angles is used. The probe is placed immediately at the inlet to the filtering apparatus.

b) Shop Air After the Roof Spray Plant

The rate of flow is small; apart from very finely divided spray water in aerosol form, the gas for analysis also contains some individual large droplets which have penetrated through the drop catching screen; it is saturated with moisture.

The probe is a special probe having drop protection plates. The probe is placed directly at the inlet of the filtering apparatus. By means of this special probe only the aerosol particles are caught during sampling, while the coarse spray water droplets, mostly retained in the spray field, are excluded.

c) Crude Gas in the Suction Lines of Soderberg Installations

The rate of flow is high; the gas for analysis contains particles of various sizes and a great deal of moisture.

A probe with an aerodynamically shaped tip is used whose opening diameter is adapted to the velocity of flow of the gas stream. The probe tube is insulated against heat loss where it lies outside the pipe line, so that there is no condensation of water vapor and it is connected by the shortest path to the filtering apparatus.

d) Final Gas in the Waste Gas Chimneys of Soderberg Installations

The rate of flow is high; the gas for analysis contains particles of various sizes and spray water droplets; it is saturated with moisture.

A probe with an aerodynamically shaped tip is used whose opening diameter is adapted to the velocity of flow of the gas stream. A thermally insulated droplet collecting bottle is placed between the probe and the filtering apparatus for separating spray water droplets.

6A.4.5 Fundamentals for Sampling Final Gases After Washing Installations

a) The Nature of the Final Gas

The waste gases in the final gas lines after the washing installations entrain more or less large amounts of spray water droplets with them, depending on the efficiency of the droplet separating devices. In the final chimneys, a considerable part of the spray water droplets is deposited. Mainly the fine and aerosol type of droplet pass to the atmosphere.

b) The Application of the Droplet Separating Bottle

It is very important to measure the droplet water content in final gas analysis (control of the efficiency of the droplet separators). For this purpose, a thermally insulated droplet separating bottle is placed between the probe and the inlet of the filtering apparatus. By slowing down and reversing the flow of the gas stream, the droplets of spray water are separated in the bottle. Only the fine and aerosol type droplets reach the filtering apparatus and then enter the final gas analysis.

For the droplet water that is separated, measurements are made of:

a) the amount separated,

b) the pH value,

c) the amount of:

F (soluble and in the dust),

S, tar and dust.

If sampling takes place at the foot of the final chimney, then sufficiently satisfactory final gas analysis results are obtained, since the droplet separating bottle reproduces the separation processes of the final gas chimney. The content of F, S, tar and dust in the droplet water are stated separately and are not counted in the final gas analysis results.

If the sampling takes place 1 - 3 meters below the mouth of the final chimney, then the amount of F, S, tar and dust in the droplet water are similarly stated separately, but are taken into consideration in assessing the final gas analysis results by adding the constituents of the droplet water to the results of the final gas analysis.

With roof spray plants, control of the efficiency of the droplet separating devices is carried out by using a normal probe instead of the special probe with droplet baffles to sample the final gas (as used for sampling shop air) a droplet separating bottle being connected after the probe.

The dimensions of the droplet separating bottle can influence the droplet separation process. Therefore, the droplet separating bottles should all be the same throughout the concern.

c) Use of a Heated Probe

If, for control purposes, the composition of a final gas after the washing plant is to be determined as satisfactorily as possible, then a heated probe is used for sampling. The probe is heated electrically to a temperature of 60 - 80°C. The probe has a length of about 80 cm and is connected to the inlet of the filtering apparatus by the shortest possible path.

The spray water droplets that are present in the final gas are evaporated in the probe. The constituents of the spray water F, S, tar and dust therefore enter into the results of the final gas analysis. Thus by using a heated probe, the composition of the final gas at the sampling point (= sum of the portion in the final gas + portion of the spray water) is obtained. Additional separation processes taking place in the final chimneys are not considered in this sampling method. Similarly, no conclusions can be drawn as to the amount and composition of the spray water from the analysis results.

6A.4.6 Choice of the Diamater of the Probe Aperture

a) Sampling in Waste Gas Lines of Soderberg Installations

The basic rule for sampling waste gases which contain dust and spray water droplets is that the velocity of the partial gas stream in the probe aperture should be equal to that of the gas stream at the point of sampling. Only when this rule is obeyed does no change occur by the sampling, in the partial gas stream, in the concentration of the particles and the particle size distribution.

To fulfill this rule, the diameter of the probe aperture must be selected according to the velocity of gas flow at the sampling point and according to the amount of gas drawn off through the apparatus for analysis. The following formula is valid:

$$d = 0.6 \sqrt{\frac{M}{v}}$$

d = diameter of the prob: mm

M = volume of analysis gas drawn off: l/h

v = gas velocity at point of sampling: m/sec.

This formula is only strictly true for aerodynamically ideal conditions, in which there is no congestion zone in front of the probe aperture. To avoid a congestion zone as far as possible, the probe should have the shape of the tip of a lead pencil (angle of cone 11.5°, d/l = 0.20) and care must be taken to ensure that the gas velocity at the point of sampling does not exceed about 8 - 10 m/sec. (installation of analysis sections).

Exchangeable probe tips of stainless steel are kept in stock with the following calibers, these corresponding to the following maximum gas velocities for a maximum sample withdrawal of 420 l/h:

d = (3.0; 3.5) 4.0; 4.5; 5.0; 6.0; 7.0 mm

v = (16.8; 12.3) 9.5; 7.5; 6.0; 4.2; 3.1 m/sec.

b) Sampling of Shop Air

The velocity of gas flow is so small that no congestion zone can be formed in front of the probe aperture. The solid particles are present as aerosols and behave practically as a gas component. The suction velocity and the shape of the probe can therefore be chosen freely.

6A.4.7 Directions for Measuring Rate of Flow of Gases and Amounts of Gas

a) Flow Velocities

Pipe Lines

Use of a "Prandtl pressure tube" with "Askania Minimeter" as differential pressure meter.

$$v = \sqrt{\frac{15.17 \times \Delta p}{R}}$$

(The formula is valid for air, density = 1.293 kg/Ncu.m.)

(at 0°C and 760 mm Hg)

Exhaust Air Chimney

Use of a vane anemometer, measureing range 0.2-20 m/sec, type 119 y of R.Fuess. Calculation of the velocity from the measured wind path over 1 min.

$$v = \frac{W\ (1\ \text{min})}{60} \qquad (\text{m/sec})$$

b) Measurement of the Amount of Gas

Pipe Lines (circular cross-section)

Use of a "Prandtl pressure tube" with "Askania Minimeter" as differential pressure meter.

In four equiplanar rings of radius 0.1; 0.2; 0.4; 1.0 the differential pressure is measured and the arithmetic mean of the pressure difference formed from them.

$$M = \frac{\pi}{4} D^2 \sqrt{\frac{19.62}{s} \times R \times \Delta p(m)} \qquad (\text{m}^3/\text{sec})$$

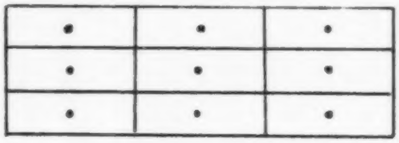
(s = density of the gas in kg/Ncu.m.
For air, s = 1.293 kg/Ncu.m.)

Exhaust Air Chimneys (rectangular cross-section)

An integrating measurement of the wind path over the whole cross-section of the waste air chimney is made. A Fuess vane anemometer, type 119 y, is used. The cross-section of the waste air chimney is divided according to the scheme shown below into 9 rectangular sections similar in shape to the complete cross-section.

The wind path is integrated continuously for half a minute in the center of each of these component sections. In this way, the sum of the average wind path of the amount of waste air for 4½ mins. is obtained.

$$M = \frac{R \times W(4\tfrac{1}{2}\ \text{min})}{270} \times Q(\text{cu.m/sec}).$$



c) The Symbols Used in the Formulae and What They Stand For

v = gas velocity: m/sec.

M = gas volume: cu.m/sec.

$W(\ )$ = wind (gas) path during the period of measurement: m.

p = differential pressure: mm H_2O

$p(m)$ = arithmetical mean of several differential pressure measurements: mm H_2O

R = reduction factor for N.T.P. (0°C, 760 mm Hg)

$= 0.359 \times \frac{p(b)}{273 + t}$ ($p(b)$ = barometer level in mm Hg, t = temperature of the gas in 0°C).

D = diameter of the pipe line in m.

Q = cross-section of the exhaust air chimney in sq.m.

6A.4.8 The Sampling Apparatus

a) The Probe Tube

The probe tube of the normal probe for sampling pipe lines and final chimneys consists of copper tubing; diameter 14/8 mm. It is bent at right angles at the front, so that the probe aperture can be directed against the gas stream. The length of the probe tube depends on the diameter of the pipe lines in which sampling is to be carried out. The front mouth is threaded and the probe tips can be screwed into the thread. The rear end is turned to about 10 mm, so that a hose with an internal diameter of 8 mm can be put on.

In the insulated probe, the insulation consists of asbestos string wound crosswise with 2 layers of glass silk tape, or of a vacuum hose with an internal diameter of 14 mm.

In the heated probe a low voltage heating coil for 36 V is applied over an insulating layer and the same insulation as is used in the insulated probe is applied over it.

b) The Droplet Separating Bottle

This consists completely of plastic. Droplet separation takes place in a chamber 48 mm in diameter and 100 mm in height. The bottle is installed within an insulating casing, so that as far as possible the bottle remains at the temperature of the analysis gas. The separated water droplets are collected in a 30 ml Plexiglas measuring cylinder attached by a thread connection. The amount of droplet water separated can therefore be checked easily.

c) The Filtering Apparatus

The filtering apparatus consists of Anticorodal coated with a protective layer of "Araldit" resin. The filtering apparatus is made by turning from a 80 mm diameter pressed bar. The gas inlet and gas exit tubes are welded in and similarly protected with "Araldit".

The sealing of the unit and the fixing of the filter thimbles is effected jointly by means of an O-ring seal. The seal is so constructed that the flanges can be screwed together metal on metal. This construction gives a constantly safe seal that cannot come loose during sampling.

The filtering apparatus is inserted in an electric oven. The temperature of the oven is held constant at 85° by means of a thermostat ("Fenval"). A rod heating element giving 150 Watt and 36 V is used for heating. The electric oven is built to the smallest possible weight, but is nevertheless proof against rain water.

A filter thimble with a simple sealed insert (Schleicher and Schull No. 603) is placed in the filtering unit. Filter thimbles with the following dimensions are used for the various analysis gases:

Crude gas VS8, S4 : dia. 38 mm, length 200 mm

Final gas VS8, S4 : dia. 38 mm, length 85 mm (if the content of dust lies below 50 mg/Ncu.m. and tar below 20 mg/Ncu.m.)

Shop air, crude and final gas : dia. 25 mm, length 70 mm

For the filter thimbles with an internal diameter of 38 mm the same filtering apparatus is used. A special filtering apparatus is required for filter thimbles with an internal diameter of 25 mm.

d) The Absorption Apparatus for the Gaseous F and S Constituents

The gaseous F and S constituents are absorbed in three glass bead absorbers connected in series (dia. 50 mm, height 450 mm). The absorbers are half-filled with glass beads of 5 mm diameter. Each contains 150 ml Na_2CO_3 solution for absorption.

The absorbers are built into an Anticorodal box which has a transparent front window of Plexiglas. The box itself has a coating of paint to protect it against corrosion.

The following items are also built into the box of the absorption apparatus:

1. A non-return valve at the inlet to the first absorber bottle. This is intended to prevent absorption alkali rising back into the filtering apparatus.

2. A plastic safety bottle attached to the outlet of the third absorber bottle to prevent impurities from the suction line to the pump station entering the absorber bottle.

3. A 90 watt, 36 v heating unit to adjust the temperature of the absorber box when the external temperature falls below 0°C.

4. An electrical distribution box for connecting the various heating units and optionally a hand lamp.

The gas inlet and exit tubes consist of p.v.c. pipes dia. 10/8. The connections are made with transparent plastic hose resistant to HF and SO_2, dia. 12/8 mm.

The connecting line between the filtering and the absorption units is also made of the same plastic hose; this should be kept as short as possible and in no case exceed 1 m.

e) The Pump Station

The pump station consists of a weatherproof box which has a transparent window. In this there are: the suction pump, the instruments for gas measurement, a 220/36 v, 500 watt cut-off transformer for the heating units for the filtering and absorption units, heating and lighting means for the pump station, as well as the electrical distribution box. The electrical installation of the pump station is to be so designed that several pump stations can be coupled together easily.

The pump station is placed on a bench at *ground level*. It is connected to the apparatus at the sampling point by the suction line, which is made of not too soft, transparent plastic hose, and by an electric cable. There is no limit to the length of the connecting line (e.g. 25 m). The excess lengths of line are stored on a holder at the pump station.

The instruments for gas measurement are connected in series as follows:

> Suction pump, "Rota" flow meter, gas meter, thermometer, vacuum gauge, safety bottle, connection from the suction line to the absorption apparatus.

The hose connections in the pump station consist of transparent plastic hose 12/8 mm in diameter. The connecting nozzles should have an external diameter. The connecting nozzles should have an external diameter of 10 mm.

A Pfeiffer (Wetzlar) "Medvak" pump, type MB 1000, is used as the *suction pump*. This pump is coupled directly to a single phase motor and is therefore very reliable in operation. Maintenance of the pump is limited to an occasional oil change (about every 2 - 3 months).

The *rate of suction* is *regulated* by means of a speed governor on the motor (coarse regulation) and by allowing ballast air to enter the suction side of the pump (fine-regulation). The ballast air is freed from dust by means of filtration through a filter thimble (e.g. dia. 38 mm, length 85 mm).

The *rate of suction* is controlled by using a *"Rota" meter* with a measuring range of up to 500 l/h (up to 8 l/min). The regulation of the suction rate with the aid of the gas meter and a stop watch is laborious and time-consuming.

The volume of gas sucked through the sampling apparatus is measured by a gas meter. Dry gas meters should be used since they have a long life and require very little maintenance. (Type MB 2.4 Elster Mainz).

The gas temperature is read from a thermometer placed at the inlet of the gas meter.

The vacuum produced by the vacuum pump is measured by means of a U-tube manometer. This has a measuring range up to 200 mm Hg.

A safety bottle is placed in the suction line at its entry in the pump station. The object of the safety bottle is to separate out any condensation water formed in the connecting line to the absorption apparatus.

6A.4.9 The Preparation of the Apparatus for Sampling

a) The sampling apparatus consisting of probe, filtering apparatus and absorption apparatus is prepared in the analytical laboratory for sampling. Probe tube, droplet separating bottle, filtering apparatus, absorber and hoses are thoroughly cleaned. (Short connecting lengths of hose are boiled in distilled water, washed with distilled water and dried free from dust).

b) The apparatus is then assembled as follows: A prepared filter thimble is placed on the cone of the filtering apparatus cover, an aluminum foil strip is wrapped round the thimble and the "O" ring pushed over it. Then the filtering apparatus is screwed together until the flanges are metal-to-metal with some pressure on them.

The absorbers are filled up to half their height with well cleaned and dried glass beads and closed with the rubber stoppers which are fitted with inlet and outlet tubes. 150 ml 5% Na_2CO_3 solution are introduced by means of a pipette (Na_2CO_3 anal. Merck). At least once a week, a blank sample is taken from each batch of Na_2CO_3 for F and S determination.

After filling with soda solution, the assembly of the absorber unit is completed. Then the probe (and possibly the droplet separating bottle, which has been placed in the insulating box) is mounted on the filtering apparatus and this is connected to the absorption apparatus. The probe aperture and the exit of the absorption apparatus are sealed with a rubber cap.

c) The filter thimbles are prepared as follows: The filter thimbles are washed with distilled water, dried and extracted with "tri". They are dried overnight on an open weighing glass in a drying cabinet at 105°C. The weighing glass is closed, allowed to cool in a desiccator and the filter thimbles are weighed in the closed weighing glass. The constant weight obtained should be better than ± 0.5 mg.

6A.4.10 Carrying Out Sampling

a) Preparations at the Sampling Station

The sampling apparatus is brought into position. The outlet of the absorber unit is connected to the hose line from the pump station. The flow velocity of the gas is now measured at the sampling point and the diameter of the probe aperture is determined. The corresponding probe tip is then screwed in and, with the probe aperture closed, the pump station is used carefully to provide suction for testing the sampling apparatus for leaks. If this check is positive, then the probe is placed in the gas stream and sampling can begin.

The rate of suction is adjusted to 360-420 l/h = 6 - 7 l/min.

b) The Sampling Procedure

To obtain a sufficient average, samples are taken for 2 days, if possible, for VS8 and S4 crude and final gases. This amounts to about 4 Ncu.m; for shop air, samples are taken for 3 days. This amounts to about 8 Ncu.m.

During sampling, the following hourly readings are entered on a recording sheet:

Time, temperature of the gas at the gas meter, vacuum, reading of the gas meter. Every hour the conditions in the furnace shop are also recorded:

> Number of ignitions, number of crust breakings, number of burners in operation in the case of VS8.

At least three times a day, the temperature of the gas at the withdrawal point is noted.

For the entire duration of analysis, the operating conditions in the shop are also entered on the recording sheet, such as: number of furnaces in operation, kg of anode mass added, kg of fluorides stirred in and, if necessary, the degree of comminution of the alumina.

c) Conclusion of Sampling

The probe is taken out of the gas stream. A few liters of air are sucked through the apparatus (so that no condensation of moisture occurs in the filter thimbles on cooling), the heating is switched off and the suction line to the pump station is clipped at the outlet of the absorption unit. After the pressure inside the sampling apparatus has equalized itself, the connecting line between the filter and absorption units is well clipped and the sampling apparatus is then separated from the suction line. After opening the clamping screw of the suction line, the suction pump in the pump station can be switched off. The probe aperture and the outlet of the absorber unit are sealed with rubber caps and the sampling apparatus taken to the analytical laboratory for attention.

6A.4.11 Dismantling and Emptying the Sampling Apparatus

First the whole apparatus is very carefully cleaned to remove adherent dirt and dust, so that when it is dismantled the analysis is not contaminated.

Then the apparatus is separated into the constituent parts - probe, possibly the droplet separating bottle, filtering apparatus and absorption unit - and the separate units are carefully sealed at the points of separation.

First the filtering apparatus is brought into a vertical position and the loose dust and tar brought into the filter thimble by tapping. Next, the filtering apparatus is unscrewed and the thimble separated from the cone and placed in a Soxhlet apparatus.

The dust and tar is washed out of the inlet tube of the filtering apparatus into a beaker using "tri". If a droplet separating bottle was used in sampling, then the contents of the probe belong to the droplet water. A weighed pad moistened with "tri" is used to clean the probe tube and the inlet tube of the filtering apparatus. The pad is prepared in precisely the same way as the filter thimbles, dried and weighed in a closed weighing glass. The "tri" that is obtained on washing the dried glass bead absorber and the glass beads is added to the quantity of "tri" in the beaker. ("tri" = trichloroethylene)

In the absorption unit the connections between the glass bead absorbers are opened and the contents of each absorber poured, together with the glass beads, into a cylindrical separating funnel of about 500 ml capacity. In this the glass beads are washed until free from alkali with wash water containing phenolphthalein. The same wash water is also used to wash the p.v.c. tubes, the connecting hose between the absorption and filter units and the non-return valve. The absorption solutions of all three absorbers and the washing solutions are collected in a 2 liter beaker, concentrated and transferred to a 1 liter graduated flask. The absorbers are inverted for drying. The glass beads are dried in a drying cabinet at 80°C. When the whole of the absorption unit is dry, it is washed with "tri" and the latter added to the "tri" washing solution in the beaker.

6A.4.12 Determination of the Tar

The combined "tri" washing solutions are filtered through the filter thimble in the Soxhlet apparatus and the beaker washed well with "tri". Then the filter thimbles, together with cleaning pad, are extracted to exhaustion in the Soxhlet apparatus. The "tri" is carefully distilled off in a previously tared 100 ml flask except for a few ml of solution. Overheating of the contents of the flask is to be avoided, so that no loss of tar occurs. The last ml of "tri" are evaporated on a water bath and the flask is dried in a drying cabinet at 80°C. Then the tar can be weighed.

The Use of Trichloroethylene as Tar Extracting Solvent

The "tri" is used instead of CS_2 as extracting agent. According to experiments made in the Rheinfelden Laboratory, the same results are obtained with "tri" as with CS_2. The "tri" is obtained directly from the manufacturer in carboys. It is predistilled over $CaCl_2$ just before use in the laboratory. This is the only certain way of obtaining anhydrous "tri" without a residue.

From time to time, the predistilled "tri" should be examined by a blank test to ensure freedom from any residue. The "tri" is used only once for extraction. The "tri" distilled off is collected and can be used in the works for degreasing purposes.

6A.4.13 Determination of the Dust

The extracted filter thimble, together with the cleaning pad, is dried in the accompanying weighing glass in a drying cabinet at 105°C. The sealed weighing glass is allowed to cool in a desiccator and the dust weight found by difference.

6A.4.14 Determination of S (Gaseous)

100 ml of the absorption solution filtrate from the 1 liter graduated flask are mixed with a few drops of hydrogen perioxide and boiled to oxidize any sulphite that may be present. Hydrochloric acid is then added until methyl red changes color and then a further 5 drops excess. The mixture is now boiled until the CO_2 has completely escaped. 3 g $AlCl_3 \cdot 6H_2O$ are added and the sulphate precipitated at the boiling temperature with an excess of 0.1 M barium chloride solution. After standing for six hours, the barium sulphate precipitate is filtered off through a blue band filter, this is ignited at 800°C and the barium sulphate weighed.

6A.4.15 Determination of the F Content

a) F (Gaseous)

10 - 100 ml of the absorption solution filtrate from the 1 liter graduated flask are pipetted into a 250 ml Claisen flask. The F is distilled over with perchloric acid to 250 ml by the Fellenberg method and determined by microtitration with 0.01-n. thorium nitrate solution.

b) F (Water-soluble) in the Dust

After weighing the dust, the filter thimble is washed with 500 ml of distilled water. The F content of an aliquot part is determined by distillation and titration with 0.01-n. thorium nitrate.

c) F (Insoluble in Water) in the Dust

Determination of the F Soluble in the Dust

The filter thimble washed with water is added to 200 ml of 5% NaOH and boiled for 15 mins. The slurry is filtered with suction and washed with hot distilled water containing phenolphthalein until an alkali-free reaction is obtained. The filtrate is made up to

1 liter. The F content is determined in 10 - 100 ml by the Fellenberg method. This method gives 95% of the F (insoluble in water) in the dust.

Control Method

The filter thimble washed with water is dried at 105°C and ashed in a covered Pt dish in a muffle furnace at 600°C. The ash is decomposed with 2 g NaOH in a Pt crucible and the F distilled over, by distillation with perchloric acid, to 250 ml and the F determined by titration with thorium nitrate solution.

6A.4.16 Processing the Contents of the Droplet Separating Bottle

The amount of the separated droplet water is measured.

The pH value of the droplet water is determined (indicator method).

The separated droplet water is filtered through a prepared (as with the filter thimbles) and tared blue band filter into a 100 ml graduated flask; the separating bottle is washed; the flask is made up to the mark.

The probe tube with probe tip and connecting hose to the droplet separator are cleaned with "tri" and a weighed pad. The separating bottle is washed with "tri" after it has been allowed to dry. The amounts of "tri" used for washing and cleaning are collected in a beaker and filtered through the blue band filter - which has been dried - used for filtering the droplet water, in which there is also the used cleaning pad. The filter is washed with "tri". The "tri" filtrate is preferably collected directly in a 100 ml flask.

Determination of the dust:	the blue band filter is dried at 105°C and weighed.
Determination of the tar:	the "tri" is evaporated, the flask is dried at 80°C and then weighed.

Determination of the F: aliquot part of the water filtrate, perchloric acid distillation, titration with 0.01-n. thorium nitrate solution.

Possible determination of F in the dust: after the dust determination, the filter is boiled with 5% NaOH solution and F determined in the filtrate.

Determination of the S: aliquot part of the aqueous filtrate, precipitation with $BaCl_2$, weighing as barium sulphate.

6A.5 Source Sampling and Analytical Techniques at a HS Soderberg Plant

The following report describes sampling and analytical techniques practiced at a United States HS Soderberg Plant.

The report was first prepared in 1968 and revised in April 1972.

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Improvement Tests on Air Control Scrubbers

Sampling and Analysis

6A.5.1 Introduction

The development of a satisfactory system for sampling and analyzing Soderberg pot gas required a major portion of the effort in testing air cleaning equipment.

This second report on the overall project covers this phase of the investigation.

6A.5.2 Definition of Problem

Sampling and analysis for the air control development work previously performed during 1952-1955 concerned itself primarily with indications of gaseous and particulate fluorides, and to a lesser extent with total solids and tar fog. The system usually attempted to evaluate one or two contaminants at a time, rather than examining total pollution.

It was felt necessary to develop a sampling and analysis system which would define the complex Soderberg contamination as a whole and as a sum of its parts as continuing outplant problems on solid and liquid fallout placed more emphasis on the solid contaminants.

6A.5.3 Conclusion

A sampling and analysis system was developed which provided a practical method in the field and in the laboratory, covered the broad range of the pollutants simultaneously, and permitted some cross checks and material balances to verify general trends in the testing. It provides definitive accounting for all important contaminants without large omissions or duplications in the categories involved.

6A.5.4 Discussion

Standard procedures for measurement of efficiency and performance of air cleaning equipment call for "determination of the average dust concentration at the inlet of the scrubber and at the outlet of the scrubber... It is....essential that the respective dust concentration be expressed in terms of weight of dust per dry standard volume or weight unit of gas". (Paragraph 4.5, "Test Procedures for Gas Scrubbers", Industrial Gas Cleaning Institute Publication No. 2). This method was used during the 1952-1955 period and was adopted for use again with the concentrations expressed in the English Engineering Units of grains per standard cubic foot of dry air.

The ideal approach to an air cleaning test would be to batchwise segregate a given mass of dirty air, weigh it, determine the amount of each impurity, clean it as the test equipment does, and then determine the residual impurities. Collection efficiencies on each impurity could be calculated and checked thru a material balance approach.

Since this is impractical, the best approximation is secured by careful sampling of inlet and outlet gas. The constant base unit for such calculations is standard cubic foot of dry air. The cross checks possible in calculating material balances force the establishment of a sound sampling and analysis system.

Soderberg pot gas exhaust contains many substances. A comprehensive list includes:

	Substance	Physical State
1.	Air, Bone Dry	Gaseous
2.	Water Vapor	Gaseous
3.	Water, Entrained	Liquid
4.	Fluoride, Gaseous	Gaseous
5.	Fluoride, Particulate	Solid
6.	Inorganic Fume	Solid Particulate Aerosol
7.	SO_2	Gaseous
8.	Inorganic & Miscellaneous Gases (CO, CO_2, SiF_4, CF_4, CS, etc.)	Gaseous

9.	Alumina, Particulate	Solid
10.	River Sand, Particulate	Solid
11.	Carbon Soot & Smoke	Solid Particulate Aerosol
12.	Tar Fog	Liquid Aerosol
13.	Gaseous Hydrocarbon	Gaseous

Numbers 8 and 10 did not enter into the considerations of these tests.

6A.5.5 Sampling System

The equipment for sampling pot gas in the inlets to the scrubbers is shown schematically in Figure 1.

#1 - A Gelman No. 1235 Inline aluminum filter holder is positioned in the duct so that the inlet right-angled glass or metal probe is located at a selected sampling point. The probe is sized for isokinetic sampling. This filter holder contains a 47 mm Gelman Type E glass fiber paper. This paper is used in high-volume samplers as it combines low pressure drop when dry with extremely fine particle retention. Type E contains an acrylic binder to give it high wet strength and will withstand temperatures to 900°F. The minimum retention efficiency for particles larger than 0.3 is 99.7% measured by Dioctyl Phthalate Penetration (DOP) Test. The efficiency is greater than 98% for particles as small as 0.05 micron.

The filter holder is mounted on the end of a 1" x 2" wood pole which can be clamped to the jig previously developed for positioning a pitot in the ducts. The jig contains 3" IPS threads which fasten into 3" pipe fittings welded to the duct. The wood strip can be positioned with a pair of vise grip pliers. Leakage is eliminated by stuffing with a rag.

The inlet duct gas normally runs about 200°F and the filter holder rises to and operates at this temperature.

#2 - As soon as possible, after the filtered gas enters tubing surrounded by atmospheric temperature, it is routed into a 27 mm ID Pyrex filter tube

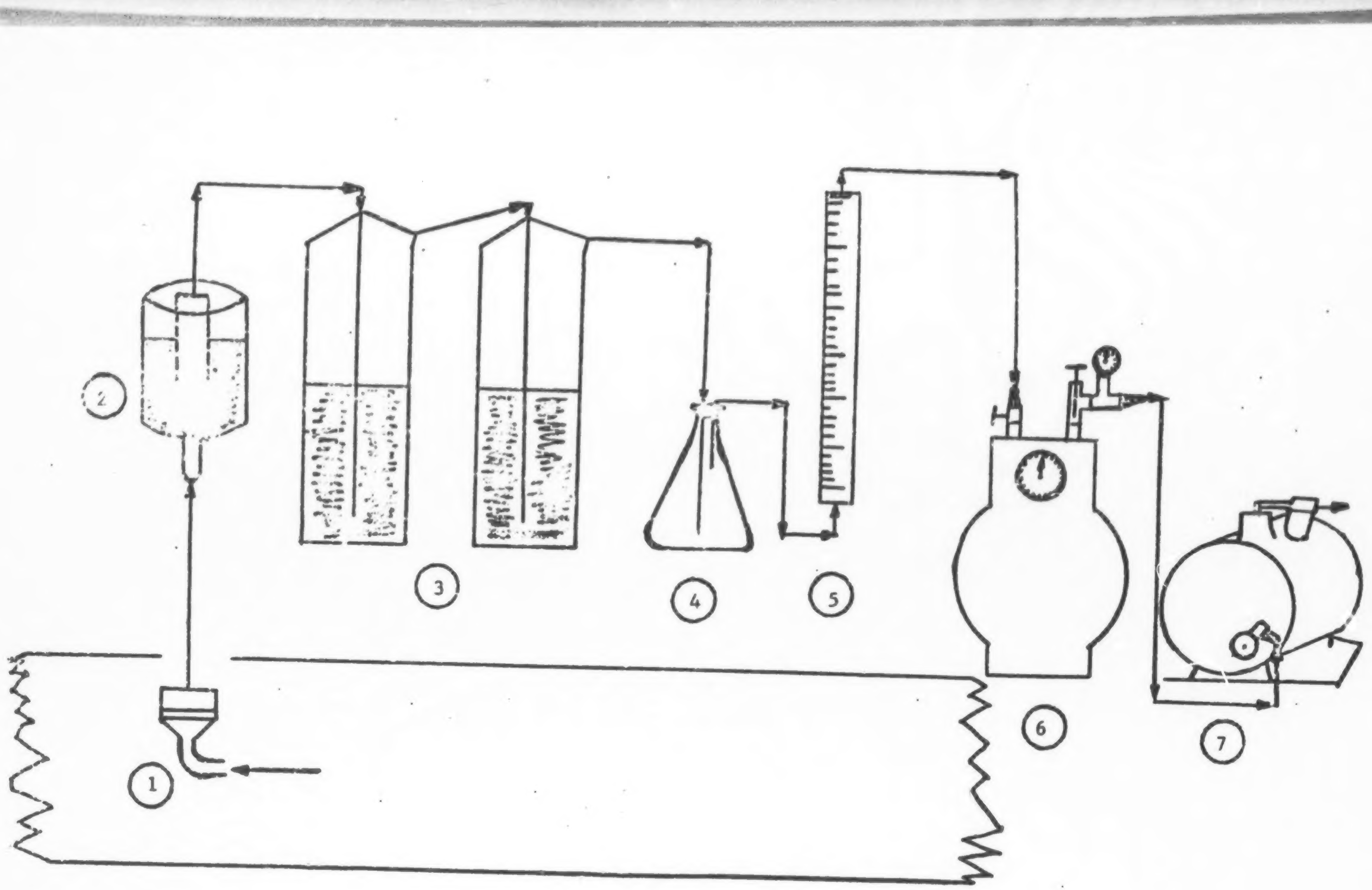


FIGURE 1
SCHEMATIC - INLET GAS SAMPLING EQUIPMENT

1 - Gelman Head and Isokinetic Glass Probe Inserted in Gas Stream
2 - Glass Head (Packed with glass wool) in ice-brine solution
3 - Two Smith-Greenberg Impingers
4 - Filter Flask
5 - F & P Flowrator
6 - Sprague Meter
7 - Rotary Vacuum Pump

packed tightly with 4.0 grams of Corning glass wool. The tube is surrounded by an ice-brine bath at 26°F ± 2°F and the gas cooled. A space is left between the small glass entrance tube and the glass wool packing. The condensible hydrocarbons deposit either on the inside of the 27 mm tube or on the glass wool packing as indicated by a yellow coloration.

#3 - The gaseous fluoride is caught in the first of two series Pyrex Smith-Greenberg impingers. The first holds 250 ml distilled water as the absorption liquid.

SO_2 is caught in the second S-G impinger. It is filled with 250 ml of 1-2% NaOH and Phenolphthalein to insure causticity.

#4 - A 50 ml filter flask trap prevents any liquid from the impingers being carried forward in the sampling train.

#5 - The instantaneous rate of sample flow is measured by a Fisher-Porter Model 10A 1027A Flowrator with a capacity of 1.2 SCFM. The normal sampling rate is either 1.0 or 0.75 CFM controlled by the valves on the Sprague Meter or Gast Pump.

#6 - The total volume of sample collected is measured with a Sprague #1A Dry Gas Test Meter with cumulating reset dials. A vacuum gauge and metal thermometer installed in the meter outlet indicate the absolute pressure and temperature of the gas as it is being measured, permitting conversion to SCF.

#7 - The air mover is a Gast pressure-vacuum pump.

The sampling equipment of Figure 1 worked well on the substantially dry inlet gas. A sample could be taken effectively with a reasonable change in pressure drop across the glass fiber filter in the Gelman Head.

Outlet sampling presented a major problem until the use of a preheater was suggested to dry the gas before filtering.

Figure 2 shows the inclusion of a ½" OD x 4'8" long copper or stainless steel sampling tube ahead of the Gelman Head. The tube is wrapped with an electric Briskeat flexible heating tape over most of its length. The heating element is wrapped with asbestos paper and glass tape to keep the moisture out. This 768 watt unit was operated at approximately 75 volts through a Variac which brings the gas to a temperature of about 60°C ± 5°.

Heating of the outlet gas apparently converted any liquid water to the vapor state. (The Gelman glass fiber filter paper will pass air at a rate 61 times as fast as it will pass liquid water). The output from the Gelman Head was then fed into the glass wool packed condensing head with as short a connection as possible.

The lack of isokinetic sampling on the fine particle size of the outlet gas is a common practice and not considered significant.

Vibration snubbers were used to protect the sampling equipment whenever necessary.

Most sample runs were 90-120 minutes duration.

All tubing joints must be tight - glass tubing was used as much as possible.

Samples are taken simultaneously in inlet and outlet positions.

6A.5.6 Analysis System

The total air contaminant removed from a sample of either inlet or outlet scrubber gas was forwarded to the laboratory in three distinct physical parts:

a) Contained on the 47 mm glass fiber filter paper.

b) Contained on glass wool in a glass sampling head, and

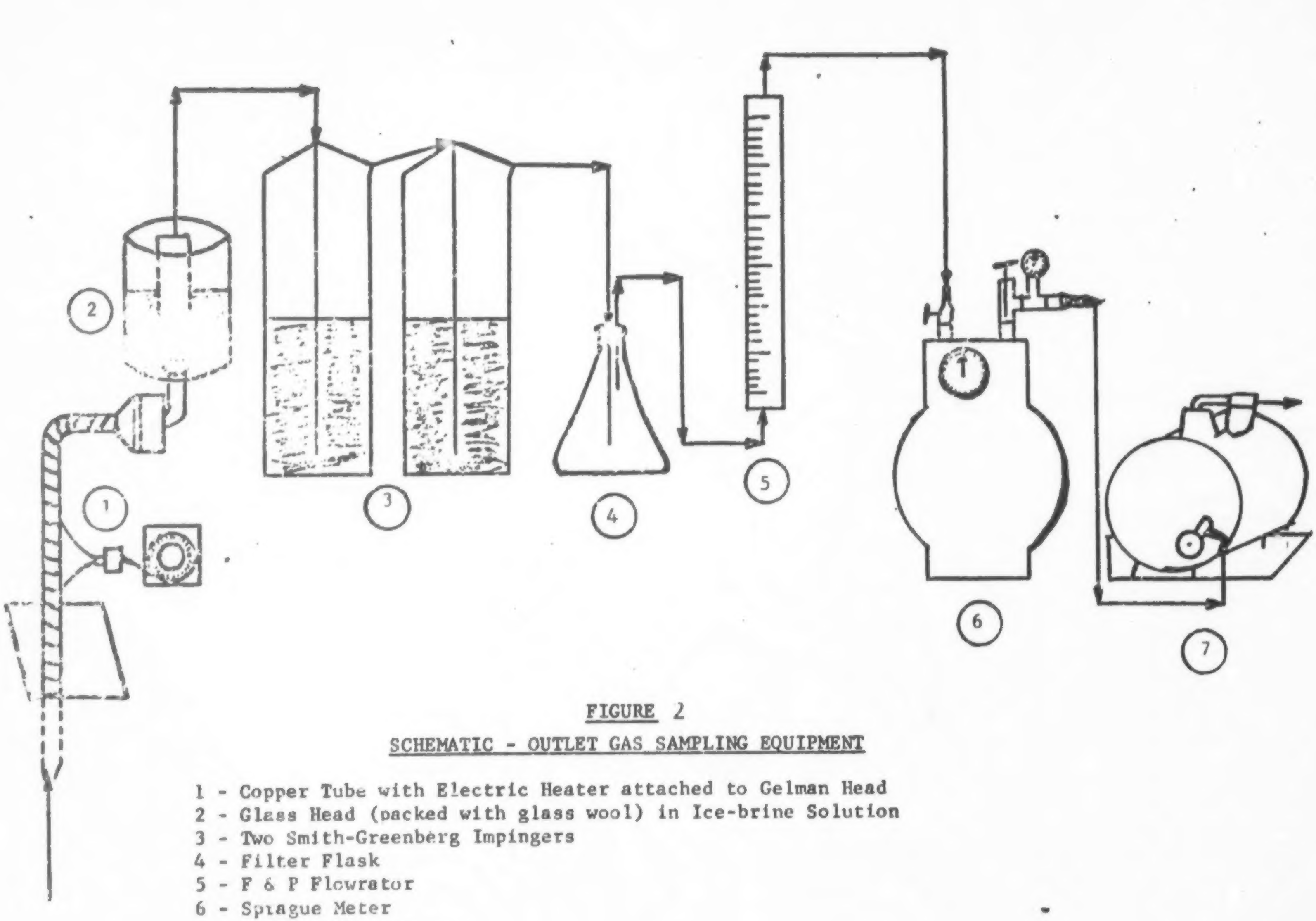


FIGURE 2

SCHEMATIC - OUTLET GAS SAMPLING EQUIPMENT

1 - Copper Tube with Electric Heater attached to Gelman Head
2 - Glass Head (packed with glass wool) in Ice-brine Solution
3 - Two Smith-Greenberg Impingers
4 - Filter Flask
5 - F & P Flowrator
6 - Sprague Meter
7 - Rotary Vacuum Pump

c) Contained in the liquid in 2 Smith-Greenberg impinger bottles.

The procedure for each of these three samples is shown schematically on Figure 3. Circled numbers "◯" refer to determinations. Squared numbers "☐" refer to gravimetric weighings. Extensive details of the laboratory procedures are included in Appendices A through E.

List and Summary of the Determinations

Sample A - 47 mm filter paper

① Total Solids - Determined gravimetrically by difference in weight of filter paper before and after sampling.

$$\textcircled{1} = \boxed{2} - \boxed{1}$$

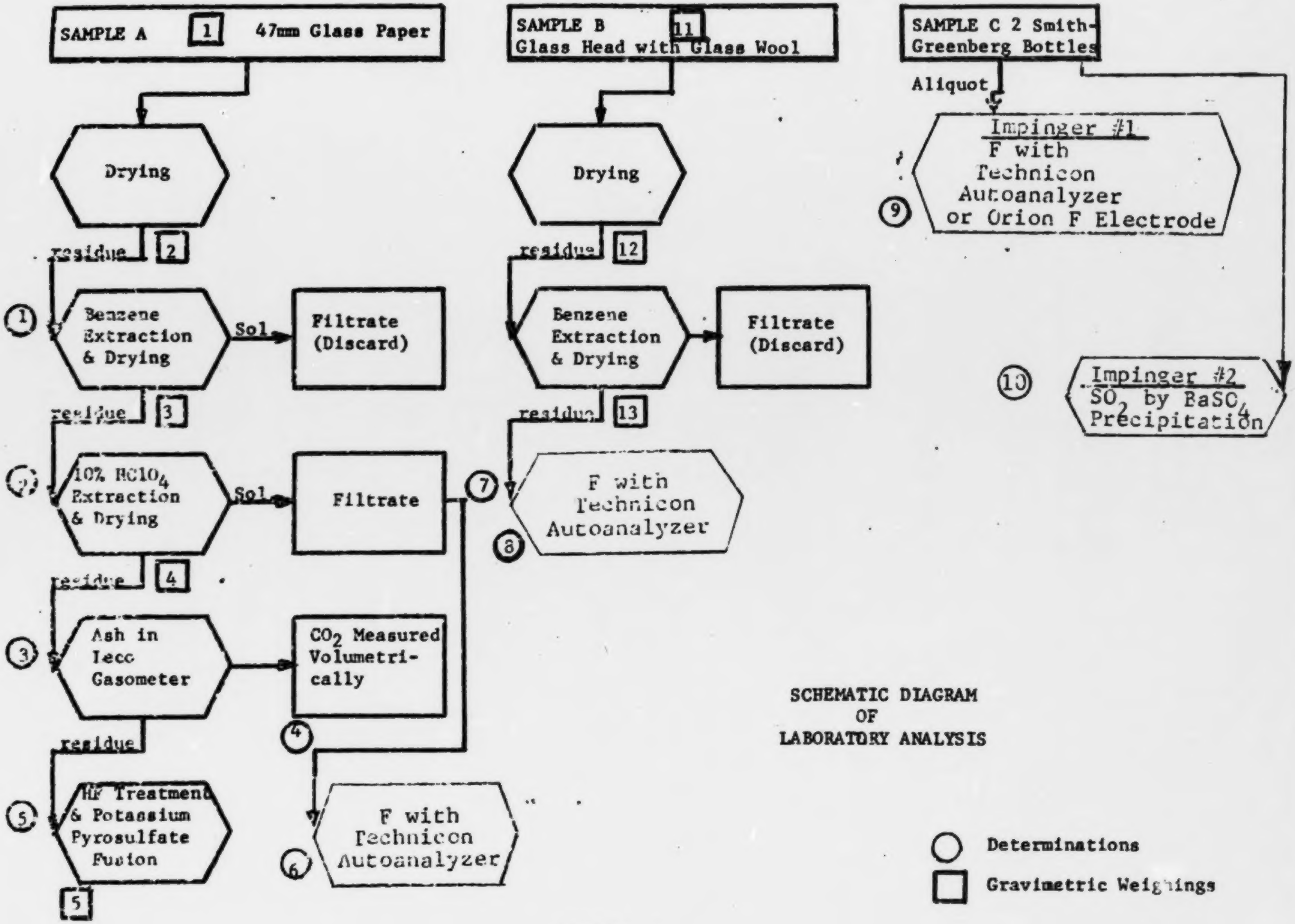
② Tar Fog (or Benzene Solubles) - Determined gravimetrically by the difference in the weight of the residue before and after a hot benzene extraction.

$$\textcircled{2} = \boxed{3} - \boxed{2}$$

③ Inorganic Fume - (The amount of fluoride materials including the metallic ions in combination). Determined gravimetrically by the difference in the weight of the residue before and after a hot 10% $HClO_4$ extraction

$$\textcircled{3} = \boxed{4} - \boxed{3}$$

④ Carbon, Soot & Smoke - Residue from perchloric acid extraction ashed in a Leco Gasometer with a flow of O_2 to convert all C to CO_2. CO_2 measured volumetrically and calculated back to C.


SAMPLE A 1 47mm Glass Paper
SAMPLE B 11 Glass Head with Glass Wool
SAMPLE C 2 Smith-Greenberg Bottles
Drying
residue 2
1 Benzene Extraction & Drying
Sol
Filtrate (Discard)
residue 3
2 10% HClO4 Extraction & Drying
Sol
Filtrate
7
residue 4
3 Ash in Lecc Gasometer
CO2 Measured Volumetrically
4
residue
5 HF Treatment & Potassium Pyrosulfate Fusion
5
6 F with Technicon Autoanalyzer
Drying
residue 12
Benzene Extraction & Drying
Filtrate (Discard)
residue 13
F with Technicon Autoanalyzer
8
Aliquot
Impinger #1
F with Technicon Autoanalyzer or Orion F Electrode
9
10
Impinger #2
SO2 by BaSO4 Precipitation
Determinations
Gravimetric Weighings

SCHEMATIC DIAGRAM
OF
LABORATORY ANALYSIS

FIGURE 3

⑤ Alumina, Particulate - Treat residue from ashing with HF to remove silicon, fuse with potassium pyrosulfate to acid solubilize, precipitate Al with alkaline NH_4, filter, ash, weight Al_2O_3.

$$\textcircled{5} = \boxed{5}$$

⑥ Particulate Fluoride - An aliquot of the filtrate from the $HClO_4$ extraction in determination 3 is used to determine F (particulate fluoride) utilizing a Technicon Autoanalyzer.

Sample B - Glass Filter Head

⑦ Condensible Tar Fog (or Benzene Solubles) - Determined gravimetrically by the difference in weight of the glass head before and after a benzene extraction with glass wool in situ.

$$\textcircled{7} = \boxed{13} - \boxed{12}$$

⑧ Gaseous Fluoride - Passage of gaseous fluoride contaminant through the 4.0 grams of glass fiber results in partial removal by reaction with the glass. The mass of glass wool is leached for ½ hour with 0.1N NaOH. F is then determined in the liquor with the Technicon Autoanalyzer.

Sample C - Two Smith-Greenberg Impingers

⑨ Gaseous Fluoride - The aqueous solution from the first impinger is run for F on the Technicon Autoanalyzer or the Orion Specific F Electrode.

⑩ SO_2 - Determined gravimetrically from the second impinger liquor by precipitation with $BaCl_2$.

Results of all determinations are reported in milligrams. These are subsequently converted to grains in the English Engineering System.

6A.5.7 Comments on Innovations to System

1. The use of the Gelman head in the hot inlet stream offered the opportunity to separate the solid and tarry impurities from the gaseous impurities at their existing temperature. The procedure also eliminated the collection of solids in the tubing before it reached a filter medium, one of the early problems.

2. The high retentivity of the Gelman glass fiber filter paper for small particle sizes trapped all solid impurity as far as could be noted. It is heat resisting. The 47 mm circles fit conveniently into the Gelman head. The laboratory reported greater consistency with its use.

3. Much trouble was experienced in trying to obtain an adequate size outlet sample. The filter head would plug quickly. Passage of gas directly into S-G bottles containing benzene followed by the filter plugged erratically and gave inconsistent results. The use of a heated probe was tried to turn any entrained waters into vapor. This was quite effective.

4. Total sample volume was first measured by striving to maintain a constant instantaneous flow rate as measured by F & P Flowrator and multiplying by the time of the run. Control was difficult, requiring frequent adjustment. Conversion to standard gas conditions was also a problem as the flowrator calibration changed with pressure. The use of the Sprague Dry Gas Test Meters was most helpful in providing a cumulative ACF figure.

5. Very erratic results and negative collection efficiencies on Tar Fog (C_6H_6 Solubles) were originally obtained. Many solutions were tried, such as passing gas into S-G bottles with C_6H_6, without positive results. The use of a glass wool filter in a container in a dry-ice bath was suggested. Some changes were required in our case, namely a brine bath rather than dry-ice, a glass container rather than metal for ease in analysis, and a dense packing of glass wool rather than loose. However, the use of the brine trap filters on both the inlet and outlet

samples brought about reasonable results on Tar Fog collection efficiencies, probably since it helps compensate for the cooling and condensing of hydrocarbon vapors in the scrubbing operation.

6. Use of Bone Dry Air as the base in concentration and material balance calculations as compared to just Air removes the effect of changes in the moisture content due to the aqueous scrubbing operation.

7. The analytical determination of Tar Fog (C_6H_6 Solubles) gravimetrically following a benzene extraction, rather than colorimetrically was found by the Lab to be more accurate. Different fractions of the tar fog affect the coloration differently.

8. Determination of Inorganic Fume permitted an evaluation of the metal ions associated with the particle fluoride impurity. The Inorganic Fume value is considered largely influenced by the preponderance of "hot pots".

9. The determination of Carbon, Soot and Smoke is considered a measure of the amount of contamination being contributed by pitch and paste, leaks and fires on the anode and on the crust. Efforts were first made to determine Carbon by ashing and weighing. Much better results were obtained by converting to CO_2 in a Leco Gasometer combustion train and measuring volumetrically.

6A.5.8 Calculations System

The mathematical logic underlying most work on improving air control involves either the comparison of concentration of output gas discharges or the comparison of collection efficiencies. Both parameters are based on concentration values expressed in these studies in "grains of pollutant per standard cubic foot of dry air".

All of the sampling and analysis efforts are used to arrive at concentration values.

Concentration is a fraction. Its numerator is a weight of impurity. The denominator is the size of the sample. The calculation methods used handled the impurity weight and sample size separately, combining them ultimately to obtain concentration values.

Weight of pollutants

As stated in the Analysis Section, the complex mixture of pollutants in a sample of scrubbed or unscrubbed gas was measured by 10 analytical determinations. Evaluation of the gas cleaning process was made on the basis of 9 contaminant categories calculated from these analytical determinations. These contaminants, their description and method of calculation are indicated on the following tables.

Contaminant Evaluated	Collection Components	Determinations Included in Weight
1. Gaseous Fluoride	Gaseous F from Impinger plus Gaseous F from Glass Head	⑨ + ⑧
2. Particulate Fluoride	Particulate F from Glass Filter Paper	⑥
3. Total Fluoride	Gaseous F plus Particulate F	⑥ + ⑧ + ⑨
4. Total Solids & Condensibles	Total Solids & Condensibles on Glass Filter Paper plus Condensible Tar Fog on Glass Head	① + ⑦
5. Tar Fog (C_6H_6 Soluble)	Benzene Soluble on Filter Paper plus Benzene Soluble on Glass Head	② + ⑦
6. Carbon, Soot & Smoke	Carbon from Filter Paper	④
7. Inorganic Fume	Inorganic Fume from Filter Paper	③
8. Alumina	Alumina from Filter Paper	⑤
9. SO_2	Gaseous SO_2 from 2nd Impinger	10

Example of Calculation for Pollutant Weight in Sample

① Laboratory Determination	② Mg	③ Grains ② x .01543	④ Additive	⑤ Weight ③ + ④	⑥ Contaminant
① Total Solids	128.4	1.981	.284	2.265	4. Total Solids & Condensibles
② Tar Fog (C_6H_6Sol)	25.8	.398	.284	.682	5. Tar Fog (C_6H_6Soluble)
③ Inorganic Fume	76.6	1.182	-	1.182	7. Inorganic Fume
④ Carbon, Soot & Smoke	27.8	.429	-	.429	6. Carbon, Soot & Smoke
⑤ Alumina	18.0	.278	-	.278	8. Alumina
⑥ Particulate F	14.7	.227	-	.227	2. Particulate Fluoride
⑦ Tar Fog (Glass Head)	18.4	.284	-	-	-
⑧ Gaseous F (Glass Head)	20.8	.321	-	-	-
⑨ Gaseous F Impingers	29.8	.460	.321	.781	1. Gaseous Fluoride
			.227 +.321 +.460	1.008	3. Total Fluoride
⑩ SO_2	-	-	-	-	9. SO_2

The contaminant weights in Column ⑤ above are carried forward to the Cleaning Efficiency Calculations.

Volume of Sample

Sprague Type 1A Dry Test Meters are widely used for the measurement of sample volume in air control testing. They provide a cumulative value for actual gas thruput (ACF) under possible changing conditions of pressure, temperature and moisture content. Calculations are concerned with adjusting the ACF measurement back to standard cubic feet of dry air - a base unit or common denominator, which is unchanged in its passage thru the scrubbing operation and which is also equivalent to a mass of dry air.

The pressure and temperature on the outlet side of the Sprague Meter were read four or five times during a run, and the values arithmetically averaged since the variation was not excessive. Humidity of the air following travel through two Smith-Greenberg impingers was assumed to be 100%.

The Buffalo Forge Company's "Fan Engineering" handbook provides a formula for the cubic feet occupied by a mixture of air and water vapor at various temperatures and pressures and containing one lb. of dry air. (6th Ed., p. 27).

$$Q = \frac{346.5 + .7535t}{b - eh}$$

Where Q = Cu.ft. of mixture per lb. of dry air in it
b = Pressure of gas in inches of mercury
e = Vapor pressure of water in inches of mercury at dry bulb temperature (available from Table, p. 6A-50)
h = Relative humidity expressed as decimal
t = Dry-bulb temperature, deg. F

Dividing the actual cubic feet of mixture (the Sprague ACF) by the number of actual cubic feet of mixture per lb. of dry air in it (Q above for the corresponding conditions) yields the number of lbs. of dry air which have been sampled thru the Sprague Meter.

It is then a simple matter to convert pounds of dry air to standard cubic feet of dry air by dividing by the density of standard dry air (0.07495 lbs/cf).

Sample Calculation

Data

Elapsed Time (Min.	Flow Rate (CFM)	Temp. °F	Vacuum (In. Hg)	Sprague Meter (ACF)	Barometer (In. Hg)
20'00"	.90	85	14.0	25.03	30.09
44'00"	.80	92	14.9	48.15	30.09
67'00"	.73	92	15.8	67.82	30.09
90'00"	.65	94	15.8	86.32	30.09
Average		91	15.1		

Sprague Meter Thruput = 86.32 ACF @ 91°F&(30.09-15)" Hg
86.32 ACF @ 551°R & 14.99" Hg

$$\text{Cu.Ft. Mixture/\#BDA=Q} = \frac{346.5 + .7535t}{b - eh}$$

$$= \frac{346.5 + .7535 \times 91}{14.99 - (1.467 \times 1.00)}$$

$$= \frac{346.5 + 68.57}{14.99 - 1.47}$$

$$= \frac{415.07}{13.52} = 30.70$$

$$\text{Lbs. BDA in Sample} = \frac{\text{ACF}}{\text{Cu.Ft. Mixture/\#BDA}} = \frac{86.32}{30.70}$$

$$= 2.812 \text{ lbs. BDA in sample}$$

$$\text{SCF BDA in Sample} = \frac{\text{\#BDA}}{.07495} = \frac{2.812}{.07495}$$

$$= 37.52 \text{ SCF BDA}$$

The standard cubic feet of bone dry air in the sample as calculated is carried forward to the Cleaning Efficiency Calculations.

Cleaning Efficiency

Figure 4, the Cleaning Efficiency Calculation Form indicates the procedure for determination of inlet concentration, outlet concentration, and scrubbing efficiency for a test. The contaminant weights in the samples and the sample volumes for previous calculations are divided to give inlet and outlet calculations.

Efficiency calculations are made from the basic concept:

$$\frac{\text{Inlet Conc.} - \text{Outlet Conc.}}{\text{Inlet Conc.}} \times 100 = \%\ \text{Efficiency}$$

FIGURE 4

CLEANING EFFICIENCY CALCULATION FORM

①		②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
		INLET				OUTLET				REMOVED	EFFIC.
CONTAMINANT		Wt. Sample (grains)	Sample Volume SCF BDA	Conc. gns/SCFA ②—③		Wt. Sample (grains)	Sample Volume SCF BDA	Conc. gns/SCFA ⑥ ÷ ⑦		④—⑧	⑩ ÷ ④
1.	Gaseous	0.781	37.52	.021		0.059	42.55	.0014		.020	95%
2.	Particulate F	0.227	↓	.006		0.057	↓	.0013		.005	83%
3.	Total F	1.008		.027		0.116		.0027		.024	89%
4.	Total Solids	2.265		.060		1.082		.0254		.035	58%
5.	Tar Fog (C_6H_6 Soluble)	0.682		.018		0.321		.0075		.010	56%
6.	Carbon, Soot & Smoke	0.429		.011		0.108		.0025		.008	73%
7.	Inorganic Fume	1.182		.032		0.478		.0112		.021	66%
8.	Alumina	0.278		.007		0.157		.0037		.003	43%
9.	SO_2	-		-		-		-		-	-

Appendix "A"

Analysis of Air Effluent Sample

The sample is collected on a tared Gelman Type E fiberglass filter paper, 47 mm in diameter, that has been brought to constant weight in the lab. Once the sample is collected and received in the lab, it is desiccated for at least forty-eight hours, then weighed (constant weight is obtained).

Benzene Solubles

1. Place filter-sample in clean numbered sinter glass crucible (coarse porosity), which is placed in corresponding numbered beaker (200 ml) mounted with stemless funnel.
2. With aid of burette extract sample with several 5 ml increments of warm benzene (not to boil) until benzene dripping from crucible is clear. (A blank is always carried along.)
3. After extractions are completed, place crucible with sample in drying oven overnight maintaining 155°C temperature.
4. Cool in desiccator for fifteen minutes and weigh: repeat Step 4 until constant weight is obtained.

Calculation: Wt. Benzene Soluble = Wt. Filter & Sample - Loss in Wt. After Benzene Extraction

Inorganic Fume (Acid Solubles)

1. Again place crucible with residue remains from sample in corresponding numbered beaker, mounted with stemless funnel.
2. Extract with six to eight 5 ml portions hot 10% $HClO_4$ (the acid dissolves bath and other inorganic fluoride material - Na_3AlF_6, CaF_2, $AlCl_3$).

3. Wash with six 5 ml portions hot distilled water. (Save combined filtrates to determine particulate fluoride).

4. Place crucible-sample in drying oven, 155°C overnight.

5. Cool in desiccator and weigh.

Calculation: Wt. Inorganic Fume = Wt. Filter & Sample after C_6H_6 extraction - Wt. Filter & Sample after $HClO_4$ extraction.

Carbon

See procedure for Carbon Determination Using Gasometer.

Note: Carbon must be determined before proceeding to alumina.

Alumina

1. Place filter sample in clean corresponding numbered platinum dish on hot plate with hood on.

2. Add ten ml Conc. HF and bake to dryness on medium heat.

3. Remove from hot plate and cool. (HF is used to remove Silicon by converting it to SiF_4 - a gas).

4. Fuse sample in hood with 3 grams Potassium Pyrosulfate.

5. Cool and put sample into solution with 25 ml of 1:1 HCl.

6. Quantitatively transfer to numbered beaker, adding 3-5 grams Ammonium Chloride and boiling the salt into solution for three minutes.

7. Remove from hot plate and cool.

8. Add 2 drops of phenol red indicator and adjust to pink color with concentrated Ammonium Hydroxide.

9. Again return beaker to hot plate and boil for one to two minutes.

10. Using Whatman No. 41H paper, filter while still warm.

11. Police thoroughly and wash about six times with hot 2% Ammonium Chloride solution.

12. Place filter with residue in numbered tared crucible and ignite in furnace for 30 minutes at 1000°C.

13. Cool in desiccator and weigh.

Calculation: Wt. Alumina = Wt. obtained after Ignition - determined blank.

Reagents:

10% $HClO_4$ - 900 ml H_2O, 100 ml Conc. $HClO_4$.

1:1 HCl - 500 ml H_2O, 500 ml Conc. Hcl.

Ammonium Chloride Solution, 2% - 10 grams dissolved in 500 ml H_2O.

Phenol Red Indicator - 0.1 gram dissolved in 100 ml H_2O.

Appendix "B"

Carbon Determination Using Gasometer

1. Preheat tube furnace for about two hours.

2. Turn burette stopcock to exhaust or furnace position and raise levelling bottle to upper cup until red levelling solution seats burette float value.

3. Place crucible (boat) with sample in tube furnace, (because of large sample size, it is representatively divided using only one-half of sample), making sure sample is in hottest region. Connect tube with oxygen flow.

4. Slowly begin oxygen flow and place levelling bottle in lower cup. (The sample will combust exothermically and use up so much of the oxygen while burning that there will be a hesitation of red fluid about 1/3 of the way down the burette bulb.) When sample has completely burned, the liquid will start down the bulb into the calibrated stem. When red levelling liquid is about 2/3 way down calibrated stem, turn off oxygen value. In no case should red solution be allowed to go below zero point on the calibrated stem.

5. Disconnect oxygen flow and remove sample, allowing the bottom of meniscus to settle to the zero point on burette stem.

6. Turn burette stockcock clockwise to caustic position and raise levelling bottle to upper cup. The red levelling solution will rise and force all the gas into the absorption vessel containing caustic (KoH) solution.

7. Lower levelling bottle by hand to below table level until the caustic rises and seats the float value (blue in color) in the absorption vessel. All gas should now be in burette. Repeat again.

8. Turn burette stopcock clockwise to lock position, keeping the levelling bottle below table level so that the float in the absorption vessel remains seated.

9. Now raise levelling bottle so the side arm reading tube is adjacent to the calibrated stem. Adjust levelling bottle height so the two menisci are on the same horizontal level. Hold for a few seconds while drainage becomes complete. Take burette reading. Reading is in milligrams of carbon.

Calculation: Total mg Carbon =
2 x burette reading - 2 x blank.

Appendix "C"

Technicon Autoanalyzer

The autoanalyzer consists of a train of interconnected modules; a sampler, a proportioning pump and manifold, a heating bath, colorimeter, and a recorder. Each unit automatically carries out a different analytical function, including sampling of unknowns and standards, metering of reagents, heating and incubation, detection and recording.

Once the samples are collected, manually prepared and transferred to the sampler in 8.5 ml sample cups, manual manipulations cease. The sample is automatically pumped through the system and distilled in hydrogen fluoride at 170°C using sulfuric acid. There is a subsequent reaction of the distillate with alizarin fluorine blue-lanthomum reagent to form a lilac-blue complex, which is measured colorimetrically at 624 manometers. All results, in absorbance and/or optical density, appear as a series of peaks on the instrument's recorder chart.

A. Glass Wool - The sample is quantitatively transferred from the head to clean stainless steel beakers. Samples are then digested for 30 minutes with 200 ml of 0.1M NaOH and kept alkaline to 2-4 drops of 1% phenolphthalein solution. The sample is cooled, filtered and diluted to a known volume (200 ml) with distilled H_2O.

B. Particulate F - Sample is extracted with 5-5 ml increments of hot 10% $HClO_4$ and an equal amount of hot distilled H_2O. Combine filtrates and dilute to 50 ml with distilled H_2O.

Appendix "D"

Analysis of Air Effluent Sample - Glass Head

The sample is collected on a tared glass head packed with approximately four grams of glass wool that has been dried and brought to constant weight in the Lab. Once the sample is collected and received in the Lab, it is dried by passing dry air through it for at least forty-eight hours, then weighed.

1. The glass head containing the sample, by its small end, is connected with rubber tubing to the stem of a short stem funnel, which has been placed into a larger metal funnel and clamped to an iron stand.
2. Through the funnel, extract the sample with ten 10-ml increments of warm benzene, or until the dripping solvent is clear. To enhance rate of filtration an air vacuum is used.
3. Place glass head with sample into a drying oven overnight at 155°C. Dessicate and weigh. (Discard filtrate)

Calculation: Wt. Benzene Solubles =
Wt. Glass Head / Wool and Sample -
Less Wt. Head ⌿ Wool ⌿ Residue
after C_6H_6 extraction.

Inorganic Fume (Acid Solubles)

1. Quantitatively remove glass wool from head with aid of forceps or other feasible means and place in 250 ml distilling flask.
2. Proceed with Willard-Winter Perchloric Acid - Steam Distillation.

Appendix "E"

Analysis of Smith-Greenberg Impinger Bottles

Bottle #1 - Gaseous Fluoride

Gaseous Fluoride is determined utilizing the Technicon Autoanalyzer or the Orion Fluoride electrode by the following procedure:

1. Aliquot 50 ml of sample and 50 ml 0.2M sodium citrate buffer into a 100 ml plastic beaker, adding stirring bar.
2. Place on magnetic stirrer and insert electrode (fluoride and reference) into solution.
3. Turn stirrer and instrument on, recording millivolt reading when stability is obtained.
4. Read ppm F from curve obtained by plotting standard solutions versus millivolts.

Bottle #2 - SO_2

Procedure

1. Adjust volume by dilution or concentration to 250 ml and adjust to pH 7.0 using 1-1 HCl.

2. Add 10 ml of 3% hydrogen peroxide, H_2O_2, and let stand for 15 minutes.

3. Using 1 + 1 HCl adjust pH to 4.0-5.0 and place on hot plate to boil.

4. While boiling add 10 ml of 10% Barium Chloride solution slowly with stirring.

5. Digest precipitate for 2 hours at 80-90°C (low heat).

6. Filter using Whatman #40 paper and wash with warm distilled water until filtrate is chloride-free to silver nitrate-nitric acid test solution.

7. Ignite precipitate at 950°C for 30 minutes.

8. Be sure to carry along blank.

Calculation:

Total mg SO_2 = mg $BaSO_4$ (residues) x 0.274.

6A.6 Reference Material

In addition to the information cited in Section 6 and that contained in this appendix, the following publications are referenced as sources of directly related technical information:

1. "Determining Dust Concentration In A Gas Stream" - American Society of Mechanical Engineers Performance Test Codes PTC-27-1957
2. "Stack And Duct Sampling For Gases And Particulates" - Gelman Instrument Co.
3. "Methods For Determination Of Velocity, Volume, Dust And Mist Content Of Gases" - Western Precipitation Division, Joy Manufacturing Co.
4. "Standards Of Performance For New Stationary Sources" - Environmental Protection Agency (Aug. 17, 1971)
5. "Sampling Atmospheric Fluorides With Glass Fiber Filters", M. R. Pack, A. C. Hill and H. M. Benedict - Journal of The Air Pollution Control Association, 13: No. 8, 374-377 (1963)
6. "A Source Sampling Technique For Particulate And Gaseous Fluorides", J. A. Dorsey, D. A. Kemnitz - Journal of Air Pollution Control Association, 18: No. 1, 12-14 (1968)
7. "Determination Of Fluoride In Air And Stack Gas Samples By Use Of An Ion Specific Electrode", L. A. Elfers, C. E. Decker, Analytical Chemistry, 40: No. 11, 1658-1661 (1968)
8. "Tentative Method Of Analysis For Fluoride Content Of The Atmosphere And Plant Tissues" - American Public Health Association, Inc., 6: No. 2, 64-101 (1969)

9. "Method 5 - Determination of Particulate Emissions from Stationary Sources" - Appendix to Federal Register, Volume 36, Number 247, December 23, 1971.

10. "Determination of Fluorides in Stack Gas: SPADNS-Zirconium Lake Method", C. E. Decker and W. S. Smith, U.S. Department of Health, Education, and Welfare. Public Health Service, Bureau of Disease Prevention and Environmental Control, National Center for Air Pollution Control, Cincinnati, Ohio, (July 1967).

11. "Analysis of Fluoride in Air and Stack Gas Samples by Use of a Specific Ion Electrode", L. A. Elfers and C. E. Decker, 154th Meeting of the American Chemical Society (September 15, 1967).

Appendix 6B

Method 13 - Determination of Total Fluoride Emissions from Stationary Sources

1. Principle and Applicability

1.1 Principle. Gaseous and particulate fluorides are withdrawn isokinetically from the source. The fluorides are collected in the impinger water and on the filter of the sampling train. The weight of total fluorides in the train is determined by the SPADNS Zirconium Lake colorimetric method.

1.2 Applicability. This method is applicable for the determination of fluoride emissions from stationary sources only when specified by the test procedures for determining compliance with New Source Performance Standards.

2. Range and Sensitivity

2.1 The analytical procedure covers the range from 0-1.4 μg/ml fluoride.

3. Interferences

3.1 Analysis. Aluminum in excess of 300 mg/liter and silicon dioxide in excess of 300 μg/liter will prevent complete recovery of fluoride. Chloride will distill over and interfere with the subsequent color reaction. Addition of 5 mg of silver sulfate (see Section 7.3.5) for each mg of chloride will prevent chloride interference.

4. Precision and Accuracy

4.1 Sampling. A relative standard deviation of ± 18% was obtained from sixteen sampling runs made on one industrial source. This measure is for combined sampling and analytical procedure and includes source variations.

4.2 Analysis. A relative standard deviation of 3 percent was obtained from twenty replicate intralaboratory determinations on a stack emission sample. A phosphate rock standard containing a certified value of 3.84 percent fluoride was analyzed by this procedure. The average of five determinations was 3.88 percent fluoride.

The color obtained when the sample and colorimetric reagent are mixed is stable for approximately two hours. After formation of the color, the temperature of the samples and standards should be nearly identical when absorbances are recorded. A 1°F temperature difference between samples and standards will produce an error of approximately 0.005 mg F/liter.

5. Apparatus

5.1 Sampling train. See Figure 6B.1. Many of the design specifications of this sampling train are described in APTD - 0581.

5.1.1 Nozzle - Stainless steel (316) with sharp, tapered leading edge.

5.1.2 Probe - Borosilicate* glass, long enough to traverse stack.

5.1.3 Pitot tube - Type S, or equivalent, attached to probe to monitor stack gas velocity.

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* Pyrex has been found suitable for this purpose. Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

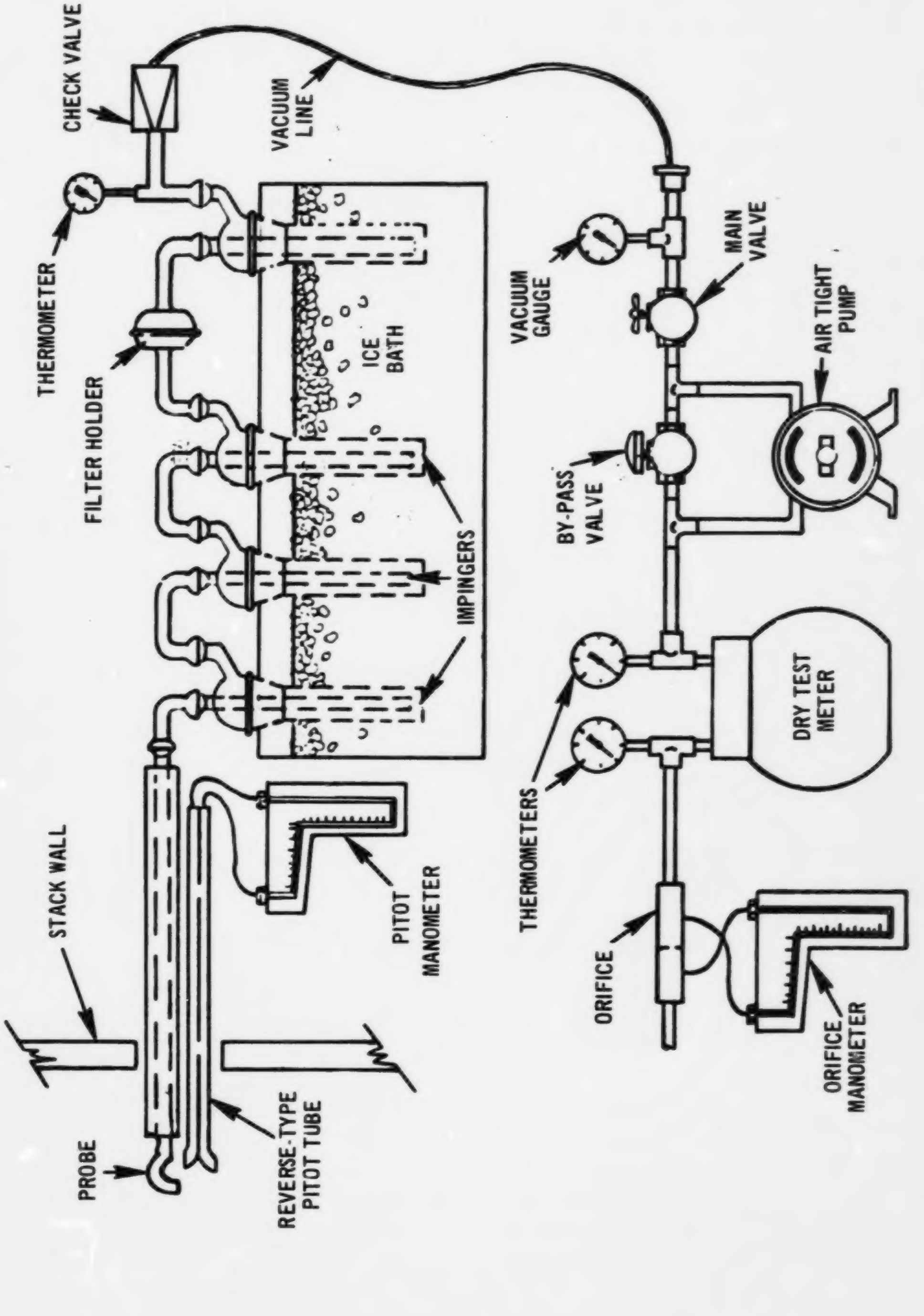

PROBE
REVERSE-TYPE PITOT TUBE
STACK WALL
PITOT MANOMETER
IMPINGERS
FILTER HOLDER
THERMOMETER
CHECK VALVE
VACUUM LINE
ICE BATH
ORIFICE
ORIFICE MANOMETER
THERMOMETERS
DRY TEST METER
BY-PASS VALVE
AIR TIGHT PUMP
VACUUM GAUGE
MAIN VALVE

Figure 6B-1. Fluoride sampling train.

5.1.4 Filter holder - Borosilicate glass.

5.1.5 Impingers - Four impingers connected as shown in Figure 6B.1 with ground glass, vacuum tight fittings. The first, third, and fourth impingers are of the Greenburg-Smith design, modified by replacing the tip with a 1/2 in. inside diameter glass tube extending to 1/2 in. from the bottom of the flask. The second impinger is of the Greenburg-Smith design with the standard tip.

5.1.6 Metering system - Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 2.8°C (5°F), dry gas meter with 2% accuracy, and related equipment, or equivalent, as required to maintain an isokinetic sampling rate and to determine sample volume.

5.1.7 Barometer - To measure atmospheric pressure to ± 2.5 mm Hg (0.1 in.)

5.2 Sample recovery.

5.2.1 Probe brush - At least as long as probe.

5.2.2 Glass wash bottle - Two.

5.2.3 Sample storage containers - Wide mouth polyethylene or polypropylene bottles, 900 ml or greater capacity.

5.2.4 Sample storage containers - Glass, 900 ml or greater capacity.

5.2.5 Graduated cylinder - 250 ml.

5.3 Analysis.

5.3.1 Distillation apparatus - Glass distillation apparatus assembled as shown in Figure 6B.2.

5.3.2 Spectrophotometer - Instrument capable of measuring absorbance at 570 nm and providing at least a 1 cm light path.

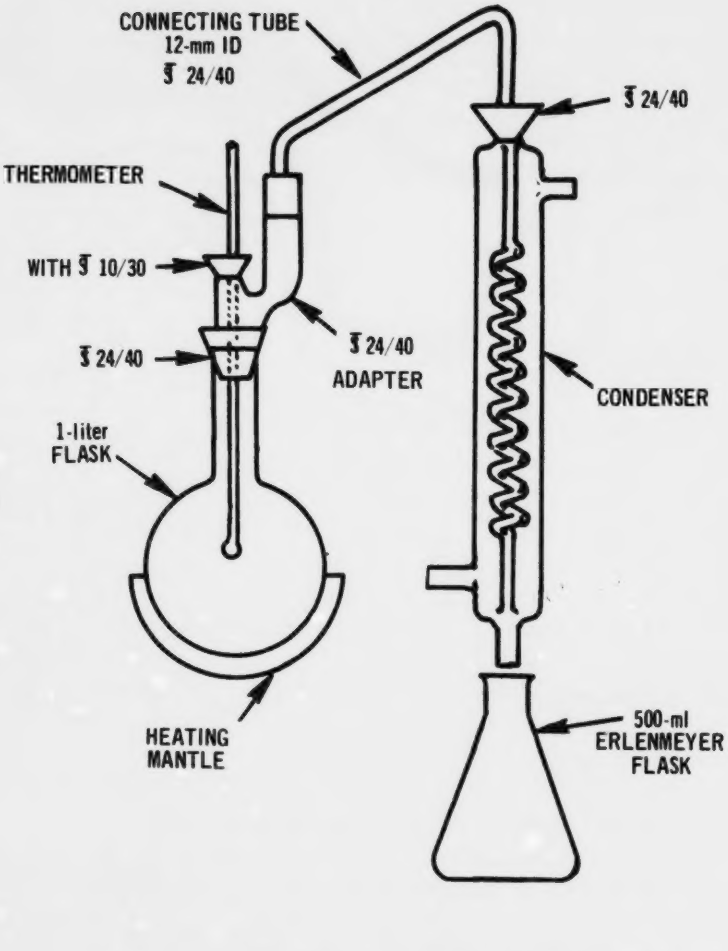

CONNECTING TUBE
12-mm ID
$ 24/40
$ 24/40
THERMOMETER
WITH $ 10/30
$ 24/40
$ 24/40
ADAPTER
CONDENSER
1-liter
FLASK
HEATING
MANTLE
500-ml
ERLENMEYER
FLASK

Figure 6B-2. Fluoride distillation apparatus.

5.3.3 Hot plate - Capable of heating to 500°C.

5.3.4 Electric muffle furnace - Capable of heating to 600°C.

5.3.5 Crucibles - Nickel or platinum, 75 to 100 ml capacity.

5.3.6 Spectrophotometer cells - 1 cm.

5.3.7 Volumetric flask - 50 ml.

5.3.8 Erlenmeyer flasks or plastic bottle - 500 ml.

5.3.9 Constant temperature bath - Capable of maintaining a constant temperature accurate to ± 0.3°C in the range of room temperature.

5.3.10 Trip balance - 300 g capacity to measure to ± 0.05 g.

6. Reagents

6.1 Sampling.

6.1.1 Filters - Whatman No. 1 filter or equivalent to fit filter holder.

6.1.2 Silica gel - Indicating type, 6 - 16 mesh, dried at 175°C (350°F) for 2 hours.

6.1.3 Water - Distilled or deionized.

6.1.4 Crushed ice.

6.2 Sample recovery.

6.2.1 Water - Distilled or deionized.

6.2.2 Acetone - Reagent grade.

6.3 Analysis.

6.3.1 Calcium oxide (CaO) - Certified grade, 0.005% fluoride or less.

6.3.2 Hydrochloric acid (HCl) - Concentrated, reagent grade.

6.3.3 Phenolphthalein Indicator - 0.1 percent in 1:1 ethanol-water mixture.

6.3.4 Silver sulfate (Ag_2SO_4) - Reagent grade.

6.3.5 Sodium hydroxide (NaOH) - Pellets, reagent grade.

6.3.6 Sulfuric acid (H_2SO_4) - Concentrated, reagent grade.

6.3.7 Sodium fluoride - Standard solution. Dissolve 0.2210 g of sodium fluoride in 1 liter of distilled water. Dilute 100 ml of this solution to 1 liter with distilled water. 1 ml of the solution contains 0.01 mg of fluoride.

6.3.8 SPADNS solution - [4,5 dihydroxy - 3 - (p - sulfophenylazo) - 2, 7 - naphthalene - disulfonic acid trisodium salt]. Dissolve 0.959 g of SPADNS reagent in 500 ml distilled water. This solution is stable indefinitely, if stored in a well-sealed bottle protected from sunlight.

6.3.9 Reference solution - Add 10 ml of SPADNS solution to 100 ml distilled water and acidify with a solution prepared by diluting 7 ml of concentrated HCl to 10 ml with distilled water. This solution is used to set the spectrophotometer zero point and is stable indefinitely.

6.3.10 SPADNS Mixed Reagent - Dissolve 0.133 g of zirconyl chloride octahydrate ($ZrOCl_2 \cdot 8H_2O$), in 25 ml distilled water. Add 350 ml of concentrated HCl and dilute to 500 ml with distilled water. Mix equal volumes of this solution and SPADNS solution to form a single reagent. This reagent is stable for approximately two years.

6.3.11 Filters - Whatman No. 541, or equivalent.

7. Procedure

7.1 Sampling.

7.1.1 Select the sampling site and the minimum number of sampling points; determine the stack pressure, temperature, moisture and range of velocity head as described in Method 1, 2, 3, and 4 (Federal Register, Volume 36, Number 247, Thursday, December 23, 1971).

7.1.2 Preparation of collection train - Place Whatman No. 1 filter into filter holder. Weigh approximately 200 g of silica gel to the nearest gram. Place 100 ml of distilled water in each of the first two impingers, leave the third impinger empty, and place the preweighed silica gel in the fourth impinger. Assemble the train without the probe as shown in Figure 6B.1 with the filter between the third and fourth impingers. Leak check the sampling train at the sampling site by plugging the inlet to the first impinger and pulling a 380 mm (15 in.) Hg vacuum. A leakage rate not in excess of 0.02 cfm at a vacuum of 380 mm (15 in.) Hg is acceptable. Attach the probe. Place crushed ice around the impingers. Add more ice during the run to keep the temperature of the gases leaving the last impinger at 21.1°C (70°F) or less.

7.1.3 Train operation. For each run, record the data required on the example sheet shown in Figure 6B.3. (Note: On the standard data sheet shown in Figure 6B.3, the entries for heater box setting, probe heater setting, and sample box temperature are not applicable to this method and should be disregarded). Take readings at each sampling point, at least every 5 minutes, and when significant changes in stack conditions necessitate additional adjustments in flow rate. To begin sampling, position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Sample for

PLANT ____________
DATE ____________
SAMPLING LOCATION ____________
SAMPLE TYPE ____________
RUN NUMBER ____________
OPERATOR ____________
AMBIENT TEMPERATURE ____________
BAROMETRIC PRESSURE ____________
STATIC PRESSURE, (P_s) ____________
FILTER NUMBER (s) ____________

FIGURE 6B-3. FIELD DATA

PROBE LENGTH AND TYPE ____________
NOZZLE I.D. ____________
ASSUMED MOISTURE, % ____________
SAMPLE BOX NUMBER ____________
METER BOX NUMBER ____________
METER $\Delta H_@$ ____________
C FACTOR ____________
PROBE HEATER SETTING ____________
HEATER BOX SETTING ____________
REFERENCE Δp ____________

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY ________ MINUTES

TRAVERSE POINT NUMBER	SAMPLING TIME, min / CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
				DESIRED	ACTUAL		INLET ($T_{m_{in}}$), °F	OUTLET ($T_{m_{out}}$), °F			

COMMENTS:

EPA (Dur) 235
4 72

the same amount of time at each traverse point. Maintain isokinetic sampling throughout the sampling period. Nomographs are available which aid in the rapid adjustment of the sampling rate without other computations. APTD - 0576 details the procedure for using these nomographs. Turn off the pump at the conclusion of each run and record the final readings. Remove the probe and nozzle from the stack.

7.2 Sample recovery. Move the impinger train to the clean-up area. Measure the volume of water in the first three impingers. Place the samples in containers as follows:

7.2.1 Container No. 1. Add the water from the first three impingers to this container. Add the filter to this container. Also add a water wash of sample exposed surfaces of the probe tip, probe, first three impingers, impinger connectors, and front of filter holder. This water wash must be performed thoroughly. Distilled or deionized water should be used. Rinse each component three separate times with water and clean the probe with the probe brush. This sample container must be made of polypropylene or polyethylene, with one exception: a glass container may be used if samples are to be stored for less than 30 days.

7.2.2 Container No. 2. Wash all sample exposed surfaces between probe tip and front of filter holder with acetone. If visible material remains, rinse or clean with a brush until the surface is clean. Add these washings to this container. This container must be made of glass.

7.2.3 Container No. 3. Transfer the silica gel from the fourth impinger to this container and seal.

7.3 Analysis. Treat the contents of each sample container as described below.

7.3.1 Container No. 1

7.3.1.1 Filter this container's contents, including the Whatman #1 filter, through filter paper, Whatman #541 or equivalent. Add an aliquot of filtrate (not exceeding 0.6 mg F) to the distillation flask as described in Section 7.3.5. For an estimate of what size aliquot does not exceed 0.6 mg F, select an aliquot of the filtrate and treat as described in Section 7.3.6. This will give an approximation of the fluoride content, but only an approximation since interfering ions have not been removed by the distillation step.

7.3.1.2 Place the Whatman #541 filter containing the insoluble matter in a nickel or platinum crucible, add a few ml of water and macerate the filter with a glass rod.

Add 100 mg CaO to the crucible and mix the contents thoroughly to form a slurry. Add a couple of drops of phenolphthlein indicator. The indicator will turn red in a basic medium. The slurry should remain basic during the evaporation of the water. If the indicator turns colorless during the evaporation, an acidic condition is indicated. If this happens add CaO until the color turns red again.

Place the crucible in a hood under infrared lamps or on a hot plate at low heat. Evaporate the water completely.

After evaporation of the water, place the crucible on a hot plate and slowly increase the temperature until the paper chars. It may take several hours for complete charring of the filter to occur. This should be done under a hood.

Place the crucible in a cold muffle furnace and gradually (to prevent smoking) increase the temperature to 600°C, and maintain until the contents are reduced to an ash.

7.3.1.3 Remove the crucible from the furnace and allow it to cool. Add approximately 4 g of NaOH pellets to the sample, return the crucible to the muffle furnace, and fuse the sample for 10 min. at 600°C.

Remove the sample from the furnace and cool to ambient temperature. Transfer the contents of the crucible to a 250 ml volumetric flask with several rinsings of warm water. To assure complete sample removal, rinse finally with two 20 ml portions of 25 percent (v/v) sulfuric acid and carefully add to the flask. Dilute to volume with distilled water. Transfer an aliquot of sample, not exceeding 0.6 mg fluoride to a distillation flask and distill as described in Section 7.3.5. This will be a separate distillation from that described in Section 7.3.1.1 for filtrate.

If the sample contains insoluble matter preventing the withdrawal of a representative aliquot, add the entire sample to the distillation flask and carry out multiple distillations (by adding 300 ml of water to the distillation flask after each distillation and redistilling) until the distillate coming from the condenser is free of fluoride. Determine that the distillate is free of fluoride by catching an aliquot (about 10 ml) of distillate as it comes from the condenser. Check the aliquot for fluoride content as described in Section 7.3.6. If this small aliquot contains fluoride, calculate the amount and add this to the total fluoride obtained for the run. If the aliquot contains fluoride, let the distillation proceed for awhile then take another aliquot to check for fluoride. Repeat this procedure until the distillate is fluoride free.

7.3.2 Container No. 2.

7.3.2.1 Filter the acetone washings through a Whatman No. 541 filter or equivalent to remove particulate matter. Thoroughly rise the residue on the filter with acetone.

The residue on the filter is treated as previously described for water insoluble particulates in Sections 7.3.1.2 and 7.3.1.3.

7.3.2.2 Add 100 mg of CaO to the filtrate and evaporate the acetone with ambient air in a forced draft hood. Add the residue to a nickel or platinum crucible, fuse the residue with NaOH, and treat as described previously in Section 7.3.1.3

7.3.3 Container No. 3. Weigh the spent silica gel and report to the nearest gram.

7.3.4 Adjustment of acid/water ratio in distillation flask - Place 400 ml of distilled water in the distilling flask and add 200 ml of concentrated H_2SO_4. Caution: Observe standard precautions when mixing the H_2SO_4 by slowly adding the acid to the flask with constant swirling. Add boiling stones and assemble the apparatus as shown in Figure 6B.2. Heat the flask until it reaches a temperature of 180°C to adjust the acid/water for subsequent distillations. Discard the distillate.

7.3.5 Distillation - Cool the contents of the distillation flask to below 100°C and add the sample from Section 7.3.1.1, 7.3.1.3, 7.3.2.1, or 7.3.2.2 contained in 300 ml of distilled water. Perform a separate distillation step for each of these fluoride fractions. If the sample contains chloride, add 5 mg Ag_2SO_4 to the flask for every mg of chloride.

Gradually increase the heat and collect all the distillate up to 180°C. The carryover of sulfate, an interference in the analysis, becomes excessive above 180°C.

The acid in the distilling flask can be used until there is carryover of interferences or poor fluoride recovery. An occasional check of fluoride recovery with standard solutions is advised.

7.3.6 Determination of concentration - Record the volume of the distillate from each distillation.

Pipet a suitable aliquot from the distillate (containing 10 µg to 40 µg fluoride) and dilute to 50 ml with distilled water. Add 10 ml of SPADNS Mixed Reagent (see Section 6.3.10) and mix thoroughly.

After mixing, place the sample in a constant temperature bath for thirty minutes before reading the absorbance with the spectrophotometer. The constant temperature bath should be at the same temperature at which the reference standards were measured (see Section 8.2).

Set the spectrophotometer to zero absorance at 570 nm with reference solution (see Section 6.3.9). Read the absorbance of the sample and determine the concentration from the calibration curve. If the concentration does not fall within the range of the calibration curve, repeat the procedure using a different size aliquot.

8. Calibration

8.1 Sampling train. Use methods and equipment which have been approved by the Administrator to calibrate the orifice meter, pitot tube, and dry gas meter.

8.2 Spectrophotometer. Prepare a standard by adding 10 ml of SPADNS Mixed Reagent to 50 ml of distilled water. Prepare a series of standards from the standard fluoride solution (see Section 6.3.7) by diluting 1, 2, 3, 4, 5, 6, and 7 ml volumes to 50 ml with distilled water and adding 10 ml of SPADNS Mixed Reagent to each. These standards will contain 0, 10, 20, 30, 40, 50, 60, and 70 µg of fluoride (0 - 1.4 µg/ml) respectively.

After mixing, place the reference standards and reference solution in a constant temperature bath for thirty minutes before reading the absorbance with the spectrophotometer. All samples should be adjusted to this same temperature before analyzing. Since a 1°F temperature difference between samples and standards will produce an error of approximately 0.005 mg F/liter, care must be taken to see that samples and standards are at nearly identical temperatures when absorbances are recorded.

With the spectrophotometer at 570 nm, use the reference solution (see Section 6.3.9) to set the absorbance at zero.

Determine the absorbances of the standards. Prepare a calibration curve by plotting µg F/50 ml versus absorbance on linear graph paper. A new standard curve should be prepared whenever a new batch of SPADNS Mixed Reagent is prepared.

9. Calculations

9.1 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 6B.3).

9.2 Dry gas volume. Correct the sample volume measured by the dry gas meter to standard conditions [21.1°C, 760 mm Hg (70°F, 29.92 inches Hg)] by using equation 6B.1

$$V_{m_{std}} = V_m \left(\frac{T_{std}}{T_m} \right) \left(\frac{P_{bar} + \frac{\Delta H}{13.6}}{P_{std}} \right) \qquad \text{Equation 6B.1}$$

where:

$V_{m_{std}}$ = Volume of gas sample through the dry gas meter (standard conditions), liter (cu ft).

V_m = Volume of gas sample through the dry gas meter (meter conditions), liter (cu ft).

T_{std} = Absolute temperature at standard conditions, 294°K (530°R).

T_m = Average dry gas meter temperature, °K (°R).

P_{bar} = Barometric pressure at the orifice meter, mm Hg (in. Hg).

ΔH = Average pressure drop across the orifice meter, mm H_2O (in. H_2O).

13.6 = Specific gravity of mercury.

P_{std} = Absolute pressure at standard conditions, 760 mm Hg (29.92 in. Hg).

9.3 Volume of water vapor.

$$V_{w_{std}} = V_{l_c}\left(\frac{\rho_{H_2O}}{M_{H_2O}}\right)\left(\frac{RT_{std}}{P_{std}}\right)$$ Equation 6B.2

where:

$V_{w_{std}}$ = Volume of water vapor in the gas sample (standard conditions), liter (cu ft).

V_{l_c} = Total volume of liquid collected in impingers and silica gel, ml. Volume of water in silica gel equals silica gel weight increase in grams times 1 ml/gram. Volume of liquid collected in impinger equals final volume minus initial volume.

ρ_{H_2O} = Density of water, 1 g/ml.

M_{H_2O} = Molecular weight of water, 18 g/g-mole (18 lb/lb - mole).

R = Ideal gas constant, 62.36 mm Hg - liter/g mole-°K (21.83 in. Hg - cu ft/lb mole - °R).

T_{std} = Absolute temperature at standard conditions, 294°K (530°R).

P_{std} = Absolute pressure at standard conditions, 760 mm Hg (29.92 in. Hg).

9.4 Moisture content.

$$B_{wo} = \frac{V_{w_{std}}}{V_{m_{std}} + V_{w_{std}}} \qquad \text{Equation 6B.3}$$

where:

B_{wo} = Proportion by volume of water vapor in the gas stream, dimensionless.

$V_{w_{std}}$ = Volume of water in the gas sample (standard conditions), liter (cu ft).

$V_{m_{std}}$ = Volume of gas sample through the dry gas meter (standard conditions), liter (cu ft).

If liquid droplets are present in the gas stream assume the stream to be saturated and use a psychrometric chart to obtain an approximation of the moisture percentage.

9.5 Concentration.

9.5.1 In the analysis, a separate distillation was performed on each of four fractions of the sample: filtrate and residue of water wash, and filtrate and residue of acetone wash. Calculate the amount of fluoride in each fraction as follows:

$$F_f = \left(\frac{V_f}{A_f}\right)\left(\frac{V_d}{A_d}\right) (\mu g\ F) \ \frac{1\ mg}{1000\ ug} \qquad \text{Equation 6B.4}$$

where:

F_f = Amount of fluoride in total fraction, mg.

V_f = Total volume of fraction, ml.

A_f = Aliquot of total fraction added to still, ml.

V_d = Volume of distillate collected, ml.

A_d = Aliquot of distillate taken for color development, ml.

$\mu g\ F$ = Concentration from the calibration curve, µg.

9.5.2 Total fluoride weight. Determine the total fluoride weight caught in a run by summing the fluoride weights of the separate fractions of the run.

9.5.3 Concentration in mg/m^3.

$$C_s = \frac{F_t}{V_{m_{std}}} 0.0283 \qquad \text{Equation 6B.5}$$

where:

C_s = Concentration of fluoride in stack gas, mg/m^3, corrected to standard conditions of 21.1°C, 760 mm Hg (70°F, 29.92 in.Hg) on a dry basis.

F_t = Total weight of fluoride in sample, mg from Section 9.5.2.

$V_{m_{std}}$ = Volume of gas sample through the dry meter (standard conditions), cu ft from equation 6B.1.

9.6 Isokinetic variation.

$$I = \frac{T_s\left[\dfrac{V_{l_c}(\rho_{H_2O})R}{M_{H_2O}} + \dfrac{V_m}{T_m}\left(P_{bar} + \dfrac{\Delta H}{13.6}\right)\right]}{\theta\ V_s\ P_s\ A_n} \times 100$$

English Units:

$$I = \frac{1.667\ T_s\left[0.00267\ V_{l_c} + \dfrac{V_m}{T_m}\left(P_{bar} + \dfrac{\Delta H}{13.6}\right)\right]}{\theta\ V_s\ P_s\ A_n}$$

Equation
6B.6

Metric Units:

$$I = \frac{1.667\ T_s\left[0.0346\ V_{l_c} + \dfrac{V_m}{1000\ T_m}\left(P_{bar} + \dfrac{\Delta H}{13.6}\right)\right]}{\theta\ V_s\ P_s\ A_n}$$

Equation
6B.7

where:

I = Percent of isokinetic sampling.

V_{l_c} = Total volume of liquid collected in impingers and silica gel, ml. Volume of water in silica gel equals silica gel weight increase in grams times 1 ml/gram. Volume of liquid collected in impingers is final volume minus initial volume.

ρ_{H_2O} = Density of water, 1 g/ml

R = Ideal gas constant, 62.36 mm Hg-liter/g mole - °K (21.83 in. Hg - cu ft/lb mole - °R).

M_{H_2O} = Molecular weight of water, 18 g/g mole (18 lb/lb - mole).

V_m = Volume of gas sample through the dry gas meter (meter conditions), m^3 (cu ft).

T_m = Absolute average dry gas meter temperature (see Figure 6B.3), °K (°R).

P_{bar} = Barometric pressure at sampling site, mm Hg (in. Hg).

ΔH = Average pressure drop across the orifice (see Figure 6B.3), mm H_2O (in. H_2O).

T_s = Absolute average stack gas temperature (see Figure 6B.3), °K (°R).

θ = Total sampling time, min.

V_s = Stack gas velocity calculated by Method 2, Equation 2 - 2, (Federal Register, Volume 36, Number 247, December 23, 1971), m/sec (ft/sec).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

A_n = Cross-sectional area of nozzle, m^2 (sq ft).

9.7 Acceptable results. The following range sets the limit on acceptable isokinetic sampling results:

If $90\% \leq I \leq 110\%$, the results are acceptable, otherwise, reject the results and repeat the test.

10. References

Bellack, Ervin, "Simplified Fluoride Distillation Method," Journal of the American Water Works Association #50: 530-6, 1958.

Bellack, Ervin, and P. J. Schoube, "Rapid Photometric Determination of Fluoride in Water," Anal. Chem. 30:2032, 1958.

Decker, C. E. and W. S. Smith, "Determination of Fluorides in Stack Gas: SPADNS - Zirconium Lake Method," PHS, NCAPC, July, 1967.

Martin, Robert M., "Construction Details of Isokinetic Source Sampling Equipment," Environmental Protection Agency, Air Pollution Control Office Publication No. APTD - 0581.

1972 Annual Book of ASTM Standards, Part 23.

Rom, Jerome J., "Maintenance, Calibration, and Operation of Isokinetic Source Sampling Equipment," Environmental Protection Agency, Air Pollution Control Office Publication No. APTD - 0576.

Standard Methods for the Examination of Water and Waste Water, published jointly by American Public Health Association, American Water Works Association and Water Pollution Control Federation, 13th Edition, 1971.

Appendix 7A

EPA Source Sampling Data

The following tables 7A-1a through 7A-8, present data obtained during the sampling of several operating plants by EPA teams. They are summarized in Section 7.5 of the report.

Table 7A-1a

FACILITY - A (Primary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/11/71	11/11/71	11/11/71	
Test Time-minutes	76	76	76	76
Production rate - TPH	0.512	0.512	0.512	0.512
Stack Effluent				
Flow rate - DSCFM	6878	6919	7033	6940
Flow rate - DSCF/ton	806,000	811,000	824,000	814,000
Temperature - ^{o}F	210	216	210	212
Water vapor - Vol. %	1.70	1.65	1.90	1.75
CO_2 - Vol. % dry	3.5	3.5	3.5	3.5
O_2 - Vol. % dry	18.7	18.7	18.7	18.7
CO - Vol. % dry	0.3	0.0	0.0	0.1
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.3234	0.4556	0.5121	0.4304
gr/ACF	0.2452	0.3402	0.3860	0.3238
lb/hr	19.06	27.02	30.87	25.65
lb/ton of product	37.6	52.0	59.6	49.7
Total Fluorides				
gr/DSCF	0.3718	0.4902	0.5365	0.4662
gr/ACF	0.2819	0.3660	0.4650	0.3709
lb/hr	21.92	29.97	32.34	27.78
lb/ton of product	42.2	56.1	62.3	53.5

Table 7A-1b

FACILITY - **FACILITY A (Primary Outlet - Fluorides)**

Summary of Results

Run number	1	2	3	Average
Date	11/11/71	11/11/71	11/11/71	
Test Time-minutes	86	88	80	85
Production rate - TPH	0.512	0.512	0.512	0.512
Stack Effluent				
Flow rate - DSCFM	7097	6958	6970	7008
Flow rate - DSCF/ton	832,000	815,000	817,000	821,000
Temperature - °F	80	80	70	77
Water vapor - Vol. %	3.11	3.28	3.10	3.16
CO_2 - Vol. % dry	3.5	3.5	3.5	3.5
O_2 - Vol. % dry	18.6	18.7	18.7	18.7
CO - Vol. % dry	0.6	0.0	0.0	0.2
Visible Emissions - % opacity	10%	10%	10%	10%
Fluorides				
Soluble				
gr/DSCF	0.0075	0.0112	0.0110	0.0099
gr/ACF	0.0071	0.0105	0.0105	0.0094
lb/hr	0.4562	0.6679	0.6571	0.5937
lb/ton of product	0.89	1.30	1.27	7.52
Total Fluorides				
gr/DSCF	0.0108	0.0145	0.0169	0.0141
gr/ACF	0.0102	0.0135	0.0162	0.0133
lb/hr	0.6569	0.8646	1.0095	0.8437
lb/ton of product	1.28	1.69	1.97	1.65

Table 7A-1c

FACILITY - A (Secondary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/8/71	11/9/71	11/9/71	
Test Time-minutes	180	180	180	180
Production rate - TPH	0.256	0.256	0.256	0.256
Stack Effluent				
Flow rate - DSCFM	143,100	143,100	143,100	143,100
Flow rate - DSCF/ton	33,540,000	33,540,000	33,540,000	33,540,000
Temperature - °F	42	47	52	47
Water vapor - Vol. %	0.212	0.626	0.0	.279
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	20.6	20.9	20.9	20.8
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.00019	0.00094	0.00078	0.00064
gr/ACF	0.00020	0.00097	0.00080	0.00066
lb/hr	0.235	1.34	0.937	0.837
lb/ton of product	0.92	5.23	3.66	3.27
Total Fluorides				
gr/DSCF	0.00029	0.00105	0.00081	0.00072
gr/ACF	0.00030	0.00107	0.00083	0.00073
lb/hr	0.353	1.47	0.98	0.93
lb/ton of product	1.38	5.74	3.83	3.65

Table 7A-1d

FACILITY - A (Secondary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/8/71	11/9/71	11/9/71	
Test Time-minutes	180	180	180	180
Production rate - TPH	0.256	0.256	0.256	0.256
Stack Effluent				
Flow rate - DSCFM	139,200	139,200	139,200	139,200
Flow rate - DSCF/ton	32,630,000	32,630,000	32,630,000	32,630,000
Temperature - ^{o}F	50	50	53	51
Water vapor - Vol. %	1.337	1.006	1[illegible]22	1.088
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	20.5	20.6	20.6	20.6
CO - Vol. % dry	0.02	0.03	0.03	0.027
Visible Emissions - % opacity	5-10%	5-10%	5-10%	5-10%
Fluorides				
Soluble				
gr/DSCF	0.00014	0.00043	0.00041	0.00033
gr/ACF	0.00014	0.00044	0.00041	0.00033
lb/hr	0.168	0.512	0.485	0.388
lb/ton of product	0.66	2.00	1.89	1.52
Total Fluorides				
gr/DSCF	0.00023	0.00800	0.00049	0.00291
gr/ACF	0.00023	0.00810	0.00049	0.00294
lb/hr	0.273	9.52	0.572	3.455
lb/ton of product	1.07	37.20*	2.24	26.26* (1.65)

* Sample not consistent with normal range, probable picked up particulate F during sample handling. Probable average shown in parenthesis.

Table 7A-1e

FACILITY - A_1 (Primary Inlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/10/72	5/10/72	5/10/72	
Test Time-minutes	96	96	96	96
Production rate - TPH	0.512	0.512	0.512	0.512
Stack Effluent				
Flow rate - DSCFM	5507	6496	5485	5826
Flow rate - DSCF/ton	645,000	760,000	643,000	683,000
Temperature - °F	267	239	252	253
Water vapor - Vol. %	1.10	0.65	1.34	1.03
CO_2 - Vol. % dry	3.3	3.3	3.3	3.3
O_2 - Vol. % dry	18.9	18.9	18.9	18.9
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.967	0.390	1.490	0.949
gr/ACF	0.687	0.289	1.080	0.6853
lb/hr	45.61	21.71	70.04	45.78
lb/ton of product	89.14	42.41	136.80	89.45
Total catch				
gr/DSCF	0.979	0.413	1.510	0.967
gr/ACF	0.696	0.306	1.090	0.697
lb/hr	46.21	22.99	70.98	46.77
lb/ton of product	90.25	44.90	138.63	91.26

Table 7A-1f

FACILITY - A_1 (Primary Outlet Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/10/72	5/10/72	5/10/72	
Test Time-minutes	288	288	288	288
Production rate - TPH	0.512	0.512	0.512	0.512
Stack Effluent				
Flow rate - DSCFM	5092	5778	5608	5493
Flow rate - DSCF/ton	598,000	677,000	657,000	644,000
Temperature - °F	51	53	53	52
Water vapor - Vol. %	2.60	2.55	2.61	2.58
CO_2 - Vol. % dry	6.0	6.0	6.0	6.0
O_2 - Vol. % dry	15.5	15.5	15.5	15.5
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0-5	0-5	0-5	0-5%
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00087	0.00041	0.00072	0.00067
gr/ACF	0.00088	0.00041	0.00073	0.00067
lb/hr	0.038	0.020	0.034	0.031
lb/ton of product	0.074	0.040	0.067	0.060
Total Catch				
gr/DSCF	0.00133	0.00104	0.00143	0.00127
gr/ACF	0.00135	0.00105	0.00145	0.00128
lb/hr	0.058	0.051	0.068	0.059
lb/ton of product	0.113	0.100	0.133	0.115

Table 7A-1g

FACILITY - A_1 (Secondary Inlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/10/72	5/10/72	5/11/72	
Test Time-minutes	270	300	270	280
Production rate - TPH	0.256	0.256	0.256	0.256
Stack Effluent				
Flow rate - DSCFM	251,970	251,970	251,970	251,970
Flow rate - DSCF/ton	984,258	984,258	984,258	984,258
Temperature - °F	50	60	70	60
Water vapor - Vol. %	0.0	0.0	0.59	0.20
CO_2 - Vol. % dry	3.3	3.3	3.3	3.3
O_2 - Vol. % dry	18.9	18.9	18.9	18.9
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00195	0.00322	0.00217	0.00245
gr/ACF	0.00204	0.00330	0.00216	0.0025
lb/hr	4.21	6.96	4.68	5.28
lb/ton of product	16.46	27.19	18.20	20.62
Total Catch				
gr/DSCF	0.00265	0.00367	0.00332	0.00321
gr/ACF	0.00277	0.00376	0.00331	0.00328
lb/hr	5.73	7.93	7.17	6.94
lb/ton of product	22.38	30.98	27.99	27.13

NA = Not Applicable

Table 7A-1h

FACILITY - A_1 (Secondary Outlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/10/72	5/10/72	5/11/72	
Test Time-minutes	358	325	330	338
Production rate - TPH	0.256	0.256	0.256	0.256
Stack Effluent				
Flow rate - DSCFM	251,970	251,970	251,970	251,970
Flow rate - DSCF/ton	984,258	984,258	984,258	984,258
Temperature - °F	50	60	70	60
Water vapor - Vol. %	1.25	1.22	0.82	
CO_2 - Vol. % dry	6.0	6.0	6.0	6.0
O_2 - Vol. % dry	15.5	15.5	15.5	15.5
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0-10	0-10	0-10	0-10
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00031	0.00047	0.0015*	0.00076
gr/ACF	0.00032	0.00047	0.0015	0.00076
lb/hr	0.667	1.006	3.190	1.621
lb/ton of product	2.61	3.95	12.46	6.34
Total Catch				
gr/DSCF	0.00057	0.00082	0.0020	0.00113
gr/ACF	0.00058	0.00083	0.0020	0.00113
lb/hr	1.221	1.766	4.329	2.440
lb/ton of product	4.77	6.90	16.91	9.53

***Stud blow**

Table 7A-1i

FACILITY - A_1 (Primary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	5/8/72	5.9.72	5/9/72	
Test Time-minutes	96	96	96	96
Production rate - TPH	0.512	0.512	0.512	0.512
Stack Effluent				
Flow rate - DSCFM	6551	5327	5664	5847
Flow rate - DSCF/ton	12,795	10,404	11,062	11,420
Temperature - °F	262	280	269	270
Water vapor - Vol. %	1.13	1.22	0.71	1.02
CO_2 - Vol. % dry	3.3	3.3	3.3	3.3
O_2 - Vol. % dry	18.9	18.9	18.9	18.9
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.335	0.348	0.438	0.374
gr/ACF	0.239	0.243	0.311	0.264
lb/hr	18.84	15.89	21.26	18.66
lb/ton of product	36.73	30.97	41.44	36.38
Total Catch				
gr/DSCF	0.344	0.366	0.452	0.387
gr/ACF	0.246	0.256	0.322	0.275
lb/hr	19.33	16.71	21.95	19.33
lb/ton of product	37.69	32.57	42.80	37.67

Table 7A-1j

FACILITY - A_1 (Primary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	5/8/72	5/9/72	5/9/72	
Test Time-minutes	288	288	288	288
Production rate - TPH	0.512	0.512	0.512	0.512
Stack Effluent				
Flow rate - DSCFM	5758.0	5999.8	5114.7	5324.2
Flow rate - DSCF/ton	663,000	586,000	588,000	612,333
Temperature - °F	52.0	52.2	51.7	52.0
Water vapor - Vol. %	2.38	2.65	2.60	2.51
CO_2 - Vol. % dry	6.0	6.0	6.0	6.0
O_2 - Vol. % dry	15.5	15.5	15.5	15.5
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	5%	5%	5%	5%
Fluorides				
Soluble				
gr/DSCF	0.000145	0.000118	0.000124	0.000129
gr/ACF	0.000147	0.000120	0.000125	0.000131
lb/hr	0.00715	0.00516	0.00535	0.00587
lb/ton of product	0.0140	0.0101	0.0104	0.0115
Total Fluorides				
gr/DSCF	0.000167	0.000118	0.000124	0.000136
gr/ACF	0.000170	0.000120	0.000125	0.000138
lb/hr	0.00825	0.00516	0.00535	0.000625
lb/ton of product	0.0161	0.0101	0.0104	0.0122

Table 7A-1k

FACILITY - A_1 (Secondary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	5/8/72	5/9/72	5/9/72	
Test Time-minutes	300	300	290	297
Production rate - TPH	0.256	0.256	0.256	0.256
Stack Effluent				
Flow rate - DSCFM	251,970	251,970	251,970	251,970
Flow rate - DSCF/ton	984,258	984,258	984,258	984,258
Temperature - °F	50	75	75	67
Water vapor - Vol. %	0.17	0.05	0.00	0.07
CO_2 - Vol. % dry	3.3	3.3	3.3	3.3
O_2 - Vol. % dry	18.9	18.9	18.9	18.9
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0003	0.0004	0.0003	0.00033
gr/ACF	0.0003	0.0004	0.0003	0.00033
lb/hr	0.64	0.84	0.70	0.73
lb/ton of product	2.50	3.28	2.76	2.84
Total Catch				
gr/DSCF	0.00031	0.0004	0.00035	0.00035
gr/ACF	0.00032	0.0004	0.00035	0.00036
lb/hr	0.683	0.873	0.766	0.774
lb/ton of product	2.67	3.41	2.99	3.02

Table 7A-1L

FACILITY - A_1 **(Secondary Outlet - Fluorides)**

Summary of Results

Run number	1	2	3	Average
Date	5/8/72	5/9/72	5/9/72	
Test Time-minutes	300	300	280	293.3
Production rate - TPH	0.256	0.256	0.256	0.256
Stack Effluent				
Flow rate - DSCFM	251,970	251,970	251,970	251,970
Flow rate - DSCF/ton	59,000,000	59,000,000	59,000,000	59,000,000
Temperature - ^oF	50	60	60	63.3
Water vapor - Vol. %	1.34	1.40	0.995	1.24
CO_2 - Vol. % dry	6.0	6.0	6.0	6.0
O_2 - Vol. % dry	15.5	15.5	15.5	15.5
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	5-10%	5-10%	5-10%	5-10%
Fluorides				
Soluble				
gr/DSCF	0.00084	0.000122	0.000065	0.000090
gr/ACF	0.000087	0.000123	0.000066	0.000092
lb/hr	0.182	0.263	0.141	0.195
lb/ton of product	0.711	1.026	0.551	0.762
Total Fluorides				
gr/DSCF	0.000084	0.000126	0.000076	0.000095
gr/ACF	0.000087	0.000128	0.000077	0.000097
lb/hr	0.182	0.273	0.165	0.207
lb/ton of product	0.711	1.066	0.643	0.806

Table 7A-1m

FACILITY - A$_2$ (Primary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	10/2-3/72	10/3-4/72	10/4-5/72	
Test Time-minutes	1442	1440	1080	1321
Production rate - TPH	0.516	0.516	0.516	0.516
Stack Effluent				
Flow rate - DSCFM	3929	4705	5187	4607
Flow rate - DSCF/ton	7614	9188	10052	8928
Temperature - ^{o}F	81	81	80	81
Water vapor - Vol. %	3.3	3.2	3.5	3.3
CO$_2$ - Vol. % dry	6.0	6.0	6.0	6.0
O$_2$ - Vol. % dry	15.5	15.5	15.5	15.5
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0-5	0-5	0-5	0-5%
Fluorides				
Soluble				
gr/DSCF	0.000084	0.00016	0.00027	0.00017
gr/ACF	0.000080	0.00015	0.00026	0.00016
lb/hr	0.0028	0.0068	0.0128	0.0075
lb/ton of product	0.0060	0.013	0.025	0.015
Total Fluorides				
gr/DSCF	0.000087	0.00016	0.00029	0.00018
gr/ACF	0.000082	0.00016	0.00028	0.00017
lb/hr	0.0030	0.0069	0.014	0.0079
lb/ton of product	0.0006	0.013	0.027	0.016

Table 7A-1n

FACILITY - A_2 (Secondary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	10/2-3/72	10/3-4/72	10/4-5/72	
Test Time-minutes	1440	1440	1440	1440
Production rate - TPH	0.258	0.258	0.258	0.258
Stack Effluent				
Flow rate - DSCFM	253,000	255,100	261,000	256,700
Flow rate - DSCF/ton	59,000,000	59,300,000	61,100,000	59,800,000
Temperature - ^{o}F	74	71	64	70
Water vapor - Vol. %	2.0	1.9	1.5	1.8
CO_2 - Vol. % dry	6.0	6.0	6.0	6.0
O_2 - Vol. % dry	15.5	15.5	15.5	15.5
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0-5%	0-5%	0-5%	0-5%
Fluorides				
Soluble				
gr/DSCF	0.00032	0.00017	0.00020	0.00023
gr/ACF	0.00031	0.00016	0.00020	0.00022
lb/hr	0.703	0.363	0.450	0.505
lb/ton of product	2.73	1.4.	1.74	1.96
Total Fluorides				
gr/DSCF	0.00035	0.00017	0.00021	0.00027
gr/ACF	0.00034	0.00016	0.00021	0.00025
lb/hr	0.757	0.367	0.468	0.531
lb/ton of product	2.93	1.42	1.81	2.05

Table 7A-2a

FACILITY - B (Primary Inlet - Particulates, Glass Filter)

Summary of Results

Run number	1	2	3	Average
Date	10/22/71	10/23/71	10/23/71	
Test Time-minutes	144	144	144	144
Production rate - TPH	0.373	0.373	0.373	0.373
Stack Effluent				
Flow rate - DSCFM	30600	30300	31000	30633
Flow rate - DSCF/ton	82037	81233	83110	82126
Temperature - °F	188	174	178	180
Water vapor - Vol. %	0.67	1.66	0.97	1.10
CO_2 - Vol. % dry	1.10	0.50	0.60	0.73
O_2 - Vol. % dry	19.90	19.70	20.40	20.00
CO - Vol. % dry	0.40	0.80	0.60	0.60
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.1498	0.1657	0.1579	0.1578
gr/ACF	0.1179	0.1314	0.1257	0.1250
lb/hr	39.28	43.03	41.95	41.30
lb/ton of product	105.3	115.3	112.5	111.0
Total Catch				
gr/DSCF	NS	NS	NS	NS
gr/ACF				
lb/hr				
lb/ton of product				

Table 7A-2b

FACILITY - B (Primary Inlet - Particulates, Paper Filter)

Summary of Results

Run number	1	2	3	Average
Date	10/20/71	10/21/71	10/22/71	
Test Time-minutes	240	144	144	176
Production rate - TPH	0.373	0.373	0.373	0.373
Stack Effluent				
Flow rate - DSCFM	31,000	32,100	31,600	31,567
Flow rate - DSCF/ton	83,110	86,059	84,718	84,630
Temperature - °F	175	176	178	176
Water vapor - Vol. %	0.58	0.66	1.15	0.8
CO_2 - Vol. % dry	0.3	1.1	1.1	0.8
O_2 - Vol. % dry	19.5	19.8	19.9	19.7
CO - Vol. % dry	1.3	0.8	0.4	0.8
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.1216	0.1786	0.1514	0.1505
gr/ACF	0.0982	0.1449	0.1209	0.1213
lb/hr	32.31	49.13	41.00	40.81
lb/ton of product	86.6	131.7	109.9	109.4
Total Catch				
gr/DSCF	NS	NS	NS	
gr/ACF				
lb/hr				
lb/ton of product				

Table 7A-2c

FACILITY - B (Primary Outlet - Particulates, Glass Filter)

Summary of Results

Run number	1	2	3	Average
Date	10/22/71	10/23/71	10/25/71	
Test Time-minutes	220	220	220	220
Production rate - TPH	0.116	0.116	0.116	0.116
Stack Effluent				
Flow rate - DSCFM	11,600	11,900	11,800	11,767
Flow rate - DSCF/ton	100,000	102,586	101,724	101,440
Temperature - °F	204	193	196	198
Water vapor - Vol. %	0.74	0.76	0.49	0.67
CO_2 - Vol. % dry	0.30	0.50	0.60	0.47
O_2 - Vol. % dry	20.30	19.70	20.10	20.03
CO - Vol. % dry	0.60	0.80	0.70	0.70
Visible Emissions - % opacity	0-10	0-10	0-10	0-10%
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.02037	0.01199	0.02123	0.01786
gr/ACF	0.0159	0.00946	0.0168	0.01404
lb/hr	2.03	1.23	2.147	1.82
lb/ton of product	17.30	10.60	18.55	15.81
Total Catch				
gr/DSCF	NS	NS	NS	NS
gr/ACF				
lb/hr				
lb/ton of product				

Table 7A-2d

FACILITY - B (Primary Outlet - Particulates, Paper Filter)

Summary of Results

Run number	1	2	3	Average
Date	10/20/71	10/21/71	10/22/71	
Test Time-minutes	220	220	220	220
Production rate - TPH	0.116	0.116	0.116	0.116
Stack Effluent				
Flow rate - DSCFM	11,700	12,500	12,600	12,267
Flow rate - DSCF/ton	100,862	107,759	108,620	105,750
Temperature - °F	187	187	194	189
Water vapor - Vol. %	0.57	0.77	0.74	0.69
CO_2 - Vol. % dry	0.4	1.1	0.3	0.6
O_2 - Vol. % dry	19.7	19.8	20.3	19.9
CO - Vol. % dry	1.0	0.8	0.6	0.8
Visible Emissions - % opacity	0	0	0	0
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0126	0.0179	0.0228	0.0178
gr/ACF	0.0101	0.0145	0.0181	0.0142
lb/hr	1.26	1.91	2.46	1.88
lb/ton of product	10.86	16.46	21.20	16.20
Total Catch				
gr/DSCF	NS	NS	NS	NS
gr/ACF				
lb/hr				
lb/ton of product				

Table 7A-2e

FACILITY - B (Primary Outlet - Particulates, Membrane Filter)

Summary of Results

Run number	1	2	3	Average
Date	10/25/71	10/26/71	10/26/71	
Test Time-minutes	220	220	220	220
Production rate - TPH	0.116	0.116	0.116	0.116
Stack Effluent				
Flow rate - DSCFM	11,800	12,100	12,200	12,033
Flow rate - DSCF/ton	101,724	104,310	105,172	103,733
Temperature - °F	196	187	189	191
Water vapor - Vol. %	0.54	0.32	0.29	0.38
CO_2 - Vol. % dry	0.6	0.5	0.5	0.5
O_2 - Vol. % dry	20.1	20.5	20.5	20.4
CO - Vol. % dry	0.7	0.6	0.6	0.6
Visible Emissions - % opacity	0	0	0	0
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0121	0.0140	0.0075	0.0112
gr/ACF	0.0096	0.0112	0.0060	0.0089
lb/hr	1.23	1.45	0.78	1.15
lb/ton of product	10.60	12.50	6.72	9.91
Total Catch				
gr/DSCF	NS	NS	NS	NS
gr/ACF				
lb/hr				
lb/ton of product				

Table 7A-2f

FACILITY - B_1 (Primary Inlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/3/72	5/3/72	5/5/72	
Test Time-minutes	96	96	96	96
Production rate - TPH	0.373	0.373	0.371	0.372
Stack Effluent				
Flow rate - DSCFM	31,945	30,323	30,232	30,833
Flow rate - DSCF/ton	85,643	81,295	81,488	82,884
Temperature - °F	151	161	173	162
Water vapor - Vol. %	0.83	0.89	0.38	0.70
CO_2 - Vol. % dry	0.4	0.4	0.4	0.4
O_2 - Vol. % dry	20.6	20.6	20.6	20.6
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.1363	0.1408	0.1374	0.1382
gr/ACF	0.1175	0.1186	0.1145	0.1169
lb/hr	37.32	36.59	35.59	36.50
lb/ton of product	100.0	98.2	95.8	98.0
Total Catch				
gr/DSCF	0.1377	0.1429	0.1396	0.1401
gr/ACF	0.1187	0.1204	0.1164	0.1185
lb/hr	37.69	37.14	36.16	37.00
lb/ton of product	101.0	99.5	97.4	99.3

Table 7A-2g

FACILITY - B_1 (Primary Outlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/4/72	5/4/72	5/5/72	
Test Time-minutes	384	383	384	384
Production rate - TPH	0.124	0.124	0.125	0.124
Stack Effluent				
Flow rate - DSCFM	11,639	11,729	11,629	11,666
Flow rate - DSCF/ton	93,863	94,589	93,032	93,556
Temperature - °F	187	188	181	185
Water vapor - Vol. %	0.46	0.46	0.50	0.47
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	19.8	19.8	19.8	19.8
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0-5	0-5	0-5	0-5
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00148	0.00137	0.00174	0.00153
gr/ACF	0.00119	0.00261	0.00141	0.00174
lb/hr	0.1475	0.1381	0.1730	0.1528
lb/ton of product	1.19	1.10	1.39	1.23
Total Catch				
gr/DSCF	0.00165	0.00313	0.00190	0.00223
gr/ACF	0.00132	0.00284	0.00154	0.00157
lb/hr	0.1644	0.3144	0.1896	0.2228
lb/ton of product	1.32	2.54	1.53	1.80

Table 7A-2h

FACILITY - B_1 (Primary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	5/1/72	5/2/72	5/2/72	
Test Time-minutes	96	96	96	96
Production rate - TPH	0.366	0.369	0.371	0.369
Stack Effluent				
Flow rate - DSCFM	31,900	31,838	30,905	31,548
Flow rate - DSCF/ton	87,158	86,282	83,302	85,495
Temperature - °F	167	160	170	166
Water vapor - Vol. %	1.15	0.93	0.84	0.97
CO_2 - Vol. % dry	0.4	0.4	0.4	0.4
O_2 - Vol. % dry	20.6	20.6	20.6	20.6
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.0412	0.0234	0.0516	0.0387
gr/ACF	0.0341	0.0197	0.0430	0.0323
lb/hr	11.28	6.37	13.67	10.44
lb/ton of product	30.7	17.3	36.8	28.2
Total Fluorides				
gr/DSCF	0.0594	0.0235	0.0724	0.0518
gr/ACF	0.0491	0.0198	0.0603	0.0430
lb/hr	16.25	6.40	19.18	13.94
lb/ton of product	44.4	17.4	51.7	37.8

Table 7A-21

FACILITY - B1 (Primary Outlet - Fluorides)

Summary of Results

Run Number	1	2	3	4	Average
Date	5/1/72	5/2/72	5/3/72	5/4/72	
Test Time-minutes	336	384	384	384	123.3
Production rate - TPH	0.122	0.123	0.124	0.124	123.3
Stack Effluent					
Flow rate - DSCFM	10,334	10,512	10,532	9,389	10,192
Flow rate - DSCF/ton	5,170,000	5,260,000	5,280,000	4,690,000	5,100,000
Temperature ^{o}F	192.2	179.1	176.1	181.0	182.1
Water vapor - Vol. %	0.00	0.00	0.33	0.49	0.21
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	19.8	19.8	19.8	19.8	19.8
CO - Vol. % dry	0.6	0.6	0.6	0.6	0.6
Visible Emissions - % opacity	0	0	0	0	0
Fluorides					
Soluble					
gr/DSCF	0.000082	0.000365	0.00023	0.000084	0.000190
gr/ACF	0.000065	0.0000290	0.00019	0.000068	0.000153
lb/hr	0.00724	0.0321	0.0210	0.0068	0.0168
lb/ton of product	0.0592	0.260	0.168	0.055	0.135
Total Fluorides					
gr/DSCF	0.000092	0.000374	0.000230	0.000084	0.000195
gr/ACF	0.000073	0.000300	0.000190	0.000069	0.000158
lb/hr	0.00814	0.0329	0.0210	0.00068	0.0172
lb/ton of product	0.0667	0.267	0.168	0.055	0.139

Table 7A-2j

FACILITY - B_1 (Roof Emissions) Fluorides

Summary of Results

Run Number	1	2	3	4	Average
Date	5/1/72	5/2/72	5/3/72	5/4-5/72	
Test Time-minutes	565	1229	1377	1350	1130
Production rate - TPH	3.72	3.72	3.72	3.72	3.70
Stack Effluent					
Flow rate - DSCFM	1,403,000	1,551,000	1,407,000	1,492,000	2,362,500
Flow rate - DSCF/ton	2,265,000	2,500,000	2,275,000	2,410,000	1,463,250
Temperature °F	84.7	91.7	106.3	106.5	97.3
Water vapor - Vol. %	0.00	0.00	0.291	0.110	0.10
CO_2 - Vol. % dry	0.4	0.4	0.4	0.4	0.4
O_2 - Vol. % dry	20.6	20.6	20.6	20.6	20.6
CO - Vol. % dry	0.0	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0	0	0	0	0
Fluorides					
Soluble					
gr/DSCF	0.000173	0.000188	0.00186	0.000158	0.000176
gr/ACF	0.000166	0.000178	0.000171	0.000146	0.000165
lb/hr	2.075	2.492	2.244	2.022	2.208
lb/ton of product	1.12	1.34	1.21	1.09	1.19
Total Fluorides					
gr/DSCF	0.000173	0.000191	0.000188	0.000160	0.000178
gr/ACF	0.000166	0.000181	0.000174	0.000148	0.000167
lb/hr	2.075	2.542	2.284	2.050	2.238
lb/ton of product	1.12	1.37	1.23	1.10	1.20

Table 7A-3a

FACILITY - C (Primary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/2/71	11/3/71	11/3/71	
Test Time-minutes	94	94	94	94
Production rate - TPH	0.292	0.292	0.292	0.292
Stack Effluent				
Flow rate - DSCFM	27,500	27,500	26,200	27,100
Flow rate - DSCF/ton	5,651,000	5,671,000	5,384,000	5,570,000
Temperature - ^{o}F	185	188	204	192
Water vapor - Vol. %	0.10	0.51	0.63	0.41
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	21.0	20.6	20.6	20.7
CO - Vol. % dry	0.0	0.1	0.1	0.07
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.0324	0.0335	0.0264	0.0308
gr/ACF	0.0269	0.0275	0.0209	0.0251
lb/hr	7.64	7.92	7.30	7.62
lb/ton of product	26.1	27.1	25.0	26.1
Total Fluorides				
gr/DSCF	0.0354	0.0364	0.0288	0.0335
gr/ACF	0.0298	0.0299	0.0228	0.0275
lb/hr	8.13	8.61	7.85	8.20
lb/ton of product	27.9	29.5	26.9	28.1

Table 7A-3b

FACILITY - C (Primary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/2/71	11/3/71	11/3/71	
Test Time-minutes	144	144	144	144
Production rate - TPH	0.625	0.625	0.625	0.625
Stack Effluent				
Flow rate - DSCFM	61,600	61,200	59,500	60,800
Flow rate - DSCF/ton	5,925,000	5,890,000	5,720,000	5,840,000
Temperature - °F	98	98	108	101
Water vapor - Vol. %	3.42	3.47	4.43	3.44
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	20.9	20.8	20.8	20.8
CO - Vol. % dry	0.3	0.0	0.0	0.0
Visible Emissions - % opacity	10%	10%	10%	10%
Fluorides				
Soluble				
gr/DSCF	0.01830	0.00913	0.00118	0.00954
gr/ACF	0.0207	0.0102	0.0129	0.0146
lb/hr	9.67	4.77	6.01	6.82
lb/ton of product	15.45	7.64	9.63	10.91
Total Fluorides				
gr/DSCF	0.0694	0.0100	0.1822	0.0872
gr/ACF	0.0785	0.0112	0.2103	0.1000
lb/hr	26.98	5.26	98.35	43.53
lb/ton of product	43.20	8.42	157.30	69.64

Table 7A-3c

FACILITY - C (Secondary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/4/71	11/5/71	11/5/71	
Test Time-minutes	180	180	180	180
Production rate - TPH	0.125	0.125	0.125	0.125
Stack Effluent				
Flow rate - DSCFM	33,400	38,400	33,400	35,100
Flow rate - DSCF/ton	16,032,000	18,432,000	16,032,000	16,830,000
Temperature - °F	66	52	68	62
Water vapor - Vol. %	1.06	0.529	0.745	0.788
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	20.8	20.7	20.7	20.7
CO - Vol. % dry	0.1	0.0	0.0	0.03
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.00283	0.00340	0.00335	0.00316
gr/ACF	0.00285	0.00360	0.00338	0.00324
lb/hr	0.803	1.150	0.969	0.974
lb/ton of product	6.43	9.20	7.75	7.79
Total Fluorides				
gr/DSCF	0.00398	0.00361	0.00373	0.00371
gr/ACF	0.00400	0.00380	0.00380	0.00387
lb/hr	1.136	1.190	1.069	1.132
lb/ton of product	9.10	9.53	8.55	9.06

Table 7A-3d

FACILITY - C (Secondary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	11/4/71	11/5/71	11/5/71	
Test Time-minutes	192	192	192	192
Production rate - TPH	0.125	0.125	0.125	0.125
Stack Effluent				
Flow rate - DSCFM	42,600	43,300	43,000	42,600
Flow rate - DSCF/ton	20,500,000	20,800,000	20,600,000	20,700,000
Temperature - °F	95	79	90	88
Water vapor - Vol. %	1.32	0.985	0.984	1.096
CO_2 - Vol. % dry	0.0	0.0	0.0	0.0
O_2 - Vol. % dry	20.7	20.7	20.7	20.7
CO - Vol. % dry	0.0	0.1	0.1	0.07
Visible Emissions - % opacity	10	10	10	10
Fluorides				
Soluble				
gr/DSCF	0.00232	0.00222	0.00233	0.00226
gr/ACF	0.00221	0.00220	0.00225	0.00222
lb/hr	0.847	0.824	0.859	0.843
lb/ton of product	6.76	6.59	6.86	6.73
Total Fluorides				
gr/DSCF	0.00255	0.00236	0.00252	0.00248
gr/ACF	0.00243	0.00234	0.00243	0.00240
lb/hr	0.931	0.876	0.929	0.912
lb/ton of product	7.45	7.02	7.43	7.30

Table 7A-4a

FACILITY - D (Primary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	2/29/72	3/1/72	3/3/72	
Test Time-minutes	121	108	108	112
Production rate - TPH	0.449	0.449	0.449	0.449
Stack Effluent				
Flow rate - DSCFM	18,277	17,762	18,458	18,160
Flow rate - DSCF/ton	40,706	39,559	41,109	40,222
Temperature - °F	269	241	241	250
Water vapor - Vol. %	0.25	1.21	1.31	0.92
CO_2 - Vol. % dry	0.97	0.97	0.97	0.97
O_2 - Vol. % dry	17.20	17.20	17.20	17.20
CO - Vol. % dry	0.13	0.13	0.13	0.13
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.1390	0.1726	0.1538	0.1551
gr/ACF	0.0980	0.1263	0.1109	0.1117
lb/hr	21.70	26.28	24.34	24.10
lb/ton of product	48.20	58.50	54.40	53.7
Total Fluorides				
gr/DSCF	0.1590	0.1947	0.1839	0.1792
gr/ACF	0.1130	0.1424	0.1325	0.1293
lb/hr	25.00	28.40	29.10	27.50
lb/ton of product	56.20	63.30	64.80	61.4

Table 7A-4b

FACILITY - D (Primary Outlet - Fluorides)

Summary of Results

Run number	1	2*	3*	Average
Date	2/29/72	3/1/72	3/1/72	
Test Time-minutes	192	192	192	192
Production rate - TPH	0.449	0.449	0.449	0.449
Stack Effluent				
Flow rate - DSCFM	19,579	18,162	19,711	19,150
Flow rate - DSCF/ton	43,650	44,850	43,950	44,150
Temperature - ^oF	239	228	237	234
Water vapor - Vol. %	0.514	1.358	1.36	1.08
CO_2 - Vol. % dry	3.40	3.40	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	0	0	0	0
Fluorides				
Soluble				
gr/DSCF	0.0015	0.0042	0.0042	0.0033
gr/ACF	0.0011	0.0031	0.0031	0.0024
lb/hr	0.252	0.720	0.234	0.402
lb/ton of product	0.561	1.560	1.560	1.23
Total Fluorides				
gr/DSCF	0.0016	0.0043	0.0043	0.0034
gr/ACF	0.0012	0.0032	0.0031	0.0025
lb/hr	0.276	0.744	0.240	0.42
lb/ton of product	0.612	1.656	1.602	1.29

* Operator experienced feed control problems this date.
Malfunction corrected before next test.
This data questionable.

Table 7A-4c

FACILITY - D (Primary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	3/2/72	3/2/72	3/3/72	
Test Time-minutes	192	192	192	192
Production rate - TPH	0.449	0.449	0.449	0.449
Stack Effluent				
Flow rate - DSCFM	19,313	20,976	19,598	19,962
Flow rate - DSCF/ton	43,050	46,650	43,800	44,500
Temperature - °F	233	235	225	231
Water vapor - Vol. %	1.54	0.97	1.31	1.28
CO_2 - Vol. % dry	3.4	3.4	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	0	0	0	0
Fluorides				
Soluble				
gr/DSCF	0.0013	0.0012	0.0008	0.0011
gr/ACF	0.0010	0.0009	0.0006	0.0008
lb/hr	0.072	0.072	0.135	0.093
lb/ton of product	0.483	0.477	0.297	0.419
Total Fluorides				
gr/DSCF	0.0014	0.0013	0.007	0.0011
gr/ACF	0.0010	0.0009	0.0007	0.0008
lb/hr	0.078	0.075	0.147	0.100
lb/ton of product	0.519	0.504	0.321	0.448

Table 7A-4d

FACILITY - D (Primary Inlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	2/28/72	2/29/72	3/3/72	
Test Time-minutes	74	72	56	67
Production rate - TPH	0.449	0.449	0.449	0.449
Stack Effluent				
Flow rate - DSCFM	17,870	22,623	17,790	19,427
Flow rate - DSCF/ton	39,799	50,385	39,621	43,268
Temperature - °F	254	256	251	254
Water vapor - Vol. %	0.57	0.99	0.91	0.82
CO_2 - Vol. % dry	3.4	3.4	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.1422	0.1396	0.1445	0.1421
gr/ACF	0.1026	1.005	0.1032	0.1021
lb/hr	21.77	27.06	22.02	23.61
lb/ton of product	48.49	60.27	49.04	52.60
Total Catch				
gr/DSCF	0.1873	0.1928	0 2054	0.1952
gr/ACF	0.1351	0.1388	0.1466	0.1402
lb/hr	28.66	37.37	31.31	32.44
lb/ton of product	63.83	83.23	69.73	72.26

Table 7A-4e

FACILITY - D (Primary Outlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	3/6/72	3/7/72	3/7/72	
Test Time-minutes	192	192	192	192
Production rate - TPH	0.150	0.150	0.150	0.150
Stack Effluent				
Flow rate - DSCFM	6627	6233	6668	6509
Flow rate - DSCF/ton	44,180	41,553	44,453	43,395
Temperature - °F	215	213	224	217
Water vapor - Vol. %	0.33	0.31	0.55	0.40
CO_2 - Vol. % dry	3.4	3.4	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	0	0	0	0
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0019	0.0023	0.0020	0.0021
gr/ACF	0.0015	0.0018	0.0015	0.0016
lb/hr	0.106	0.118	0.113	0.112
lb/ton of product	0.71	0.79	0.75	0.75
Total Catch				
gr/DSCF	0.0061	0.0064	0.0059	0.0061
gr/ACF	0.0048	0.0049	0.0045	0.0047
lb/hr	0.344	0.344	0.333	0.333
lb/ton of product	2.30	2.16	2.22	2.22

Table 7A-4f

FACILITY - D (Primary Outlet - Particulates, Thimble)

Summary of Results

Run number	1	2	3	Average
Date	2/28/72	2/28/72	3/3/72	
Test Time-minutes	75	144	144	121
Production rate - TPH	0.150	0.150	0.150	0.150
Stack Effluent				
Flow rate - DSCFM	6725	6248	7139	6704
Flow rate - DSCF/ton	44,833	41,653	47,593	44,693
Temperature - °F	232	233	223	229
Water vapor - Vol. %	0.18	0.80	1.03	0.67
CO_2 - Vol. % dry	3.4	3.4	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	0	0	0	0
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0026	0.0065	0.0035	0.0042
gr/ACF	0.0020	0.0048	0.0026	0.0031
lb/hr	0.148	0.344	0.207	0.233
lb/ton of product	0.98	2.29	1.38	1.55
Total Catch				
gr/DSCF	0.0144	0.0191	0.0124	0.0153
gr/ACF	0.0109	0.0143	0.0093	0.0153
lb/hr	0.827	1.019	0.757	0.867
lb/ton of product	5.50	6.80	5.04	5.78

Table 7A-4g

FACILITY - D (Roof Emissions)

Summary of Results

Run number	1	2	3	Average
Date	3/1-2/72	3/2-3/72		
Test Time-minutes	1441	1200		1320.5
Production rate - TPH	1.740	1.740		1.740
Stack Effluent				
Flow rate - DSCFM	(665,310)	(754,152)		709,731
Flow rate - DSCF/ton	382,000	433,000		407,500
Temperature - ^{o}F	105.9	103.5		104.7
Water vapor - Vol. %	0.0	0.0		0.0
CO_2 - Vol. % dry	1.8	1.8		1.8
O_2 - Vol. % dry	20.8	20.8		20.8
CO - Vol. % dry	0.8	0.8		0.8
Visible Emissions - % opacity	0	0		0
Fluorides				
Soluble				
gr/DSCF	0.00022	0.00036		0.00029
gr/ACF	0.00020	0.00033		0.00027
lb/hr	1.28	2.32		1.80
lb/ton of product	0.73	1.33		1.03
Total Fluorides				
gr/DSCF	0.00026	0.00040		0.00033
gr/ACF	0.00024	0.00036		0.00030
lb/hr	1.50	2.57		2.04
lb/ton of product	0.86	1.48		1.17

Table 7A-4h

FACILITY - D_1 (Primary Outlet - Fluorides)

Summary of Results

Run number	4	5	6	Average
Date	3/6/72	3/7/72	3/7/72	
Test Time-minutes	192	192	192	192
Production rate - TPH	0.449	0.449	0.449	0.449
Stack Effluent				
Flow rate - DSCFM	19,671.3	18,868.2	18,903.00	19,147.00
Flow rate - DSCF/ton	43,800	42,000	42,150	42,650
Temperature - $^{\circ}$F	209.8	216.3	221.3	215.8
Water vapor - Vol. %	0.374	0.353	0.700	0.476
CO_2 - Vol. % dry	3.4	3.4	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	0	0	0	0
Fluorides				
Soluble				
gr/DSCF	0.0012	0.0009	0.0011	0.0011
gr/ACF	0.0009	0.0007	0.0008	0.0008
lb/hr	0.1998	0.1506	0.1761	0.1755
lb/ton of product	0.484	0.336	0.393	0.404
Total Fluorides				
gr/DSCF	0.0013	0.0011	0.0012	0.0012
gr/ACF	0.0010	0.0008	0.0009	0.0009
lb/hr	0.2223	0.1710	0.1968	0.1967
lb/ton of product	0.495	0.381	0.438	0.438

Table 7A-4i

FACILITY - D_1 (Primary Outlet - Single Point)

Summary of Results

Run number	1	2	3	Average
Date	3/6/72	3/7/72	3/7/72	
Test Time-minutes	192	192	192	192
Production rate - TPH	0.150	0.150	0.150	0.150
Stack Effluent				
Flow rate - DSCFM	7646	7757	7219	7541
Flow rate - DSCF/ton	50,973	51,713	48,126	50,273
Temperature - °F	210	211	225	215
Water vapor - Vol. %	1.98	0.66	0.87	1.17
CO_2 - Vol. % dry	3.4	3.4	3.4	3.4
O_2 - Vol. % dry	16.3	16.3	16.3	16.3
CO - Vol. % dry	0.3	0.3	0.3	0.3
Visible Emissions - % opacity	0	0	0	0
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0007	0.0003	0.0005	0.0005
gr/ACF	0.0005	0.0003	0.0004	0.0004
lb/hr	0.045	0.022	0.029	0.032
lb/ton of product	0.30	0.15	0.19	0.21
Total Catch				
gr/DSCF	0.0008	0.0005	0.0006	0.0006
gr/ACF	0.0006	0.0004	0.0004	0.0005
lb/hr	0.054	0.030	0.037	0.040
lb/ton of product	0.36	0.20	0.25	0.27

Table 7A-5a

FACILITY - E (Primary Inlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	5/15/72	5/15/72	5/16/72	
Test Time-minutes	96	96	96	96
Production rate - TPH	0.441	0.441	0.441	0.441
Stack Effluent				
Flow rate - DSCFM	49,267	48,235	47,052	48,184
Flow rate - DSCF/ton	111,716	109,376	106,693	109,260
Temperature - °F	213	216	217	215
Water vapor - Vol. %	0.90	1.45	1.10	1.15
CO_2 - Vol. % dry	0.7	0.7	0.7	0.7
O_2 - Vol. % dry	19.9	19.9	19.9	19.9
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Fluorides				
Soluble				
gr/DSCF	0.0255	0.0363	0.0401	0.0340
gr/ACF	0.0200	0.0282	0.0311	0.0264
lb/hr	10.77	15.00	16.16	13.97
lb/ton of product	24.40	34.00	36.60	31.67
Total Fluorides				
gr/DSCF	0.0365	0.0538	0.0593	0.0499
gr/ACF	0.0286	0.0417	0.0460	0.0387
lb/hr	15.43	22.22	23.90	20.51
lb/ton of product	35.00	50.40	54.20	46.53

Table 7A-5b

FACILITY - E (Primary Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	5/15/72	5/12/72	5/16/72	
Test Time-minutes	240	240	240	240
Production rate - TPH	0.441	0.441	0.441	0.441
Stack Effluent				
Flow rate - DSCFM	50,596	48,795	47,121	48,837
Flow rate - DSCF/ton	115,000	111,000	107,000	111,000
Temperature - °F	57.4	57.6	83.7	66.3
Water vapor - Vol. %	5.42	5.76	5.64	5.61
CO_2 - Vol. % dry	0.6	0.6	0.6	0.6
O_2 - Vol. % dry	20.2	20.2	20.2	20.2
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	10%	10%	10%	10%
Fluorides				
Soluble				
gr/DSCF	0.00040	0.00039	0.00046	0.00043
gr/ACF	0.00039	0.00031	0.00042	0.00038
lb/hr	0.174	0.162	0.186	0.174
lb/ton of product	0.394	0.365	0.422	0.394
Total Fluorides				
gr/DSCF	0.00042	0.00044	0.00046	0.00044
gr/ACF	0.00040	0.00033	0.00042	0.00038
lb/hr	0.181	0.169	0.186	0.179
lb/ton of product	0.410	0.382	0.422	0.405

Table 7A-5c

FACILITY - E (Roof Emissions) Fluorides

Summary of Results

Run Number	1	2	3	4	Average
Date	5/12/72	5/15/72	5/16/72	5/17/72	
Test Time-minutes	1062	735	645	450	723
Production rate - TPH	2.64	2.64	2.64	2.64	2.64
Stack Effluent					
Flow rate - DSCFM	2,811,000	2,811,000	2,811,000	2,811,000	2,811,000
Flow rate - DSCF/ton	1,065,000	1,065,000	1,065,000	1,065,000	1,065,000
Temperature °F	75	70	70	65	89
Water vapor - Vol. %	0	0.87	0.95	0.64	0.62
CO_2 - Vol. % dry	0.7	0.7	0.7	0.7	0.7
O_2 - Vol. % dry	19.9	19.9	19.9	19.9	19.9
CO - Vol. % dry	0.0	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	0	0	0	0	0
Fluorides					
Soluble					
gr/DSCF	0.00012	0.00021	0.00024	0.00030	0.00022
gr/ACF	0.00012	0.00021	0.00024	0.00030	0.00022
lb/hr	2.87	5.12	5.87	7.30	5.29
lb/ton of product	1.09	1.93	2.22	2.76	2.00
Total Fluorides					
gr/DSCF	0.00012	0.00022	0.00025	0.00031	0.00022
gr/ACF	0.00012	0.00022	0.00025	0.00031	0.00022
lb/hr	2.92	5.32	6.04	7.54	5.45
lb/ton of product	1.10	2.01	2.28	2.85	2.06

Table 7A-5d

FACILITY - E (Primary Inlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/16/72	5/16/72	5/17/72	
Test Time-minutes	96	96	96	96
Production rate - TPH	0.441	0.441	0.441	0.441
Stack Effluent				
Flow rate - DSCFM	47,895	48,389	47,960	48,081
Flow rate - DSCF/ton	108,605	109,725	108,752	109,027
Temperature - °F	214	219	208	214
Water vapor - Vol. %	1.31	1.10	0.50	0.97
CO_2 - Vol. % dry	0.7	0.7	0.7	0.7
O_2 - Vol. % dry	19.9	19.9	19.9	19.9
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0653	0.0782	0.0703	0.0713
gr/ACF	0.0508	0.0604	0.0556	0.0556
lb/hr	26.81	32.42	28.88	29.37
lb/ton of product	60.8	73.5	65.5	66.60
Total Catch				
gr/DSCF	0.0801	0.0965	0.0860	0.0875
gr/ACF	0.0623	0.0746	0.0681	0.0683
lb/hr	32.87	40.00	35.35	36.07
lb/ton of product	74.5	90.8	80.1	81.8

Table 7A-5e

FACILITY - E (Primary Outlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	5/16/72	5/17/72	5/17/72	
Test Time-minutes	240	240	240	240
Production rate - TPH	0.441	0.441	0.441	0.441
Stack Effluent				
Flow rate - DSCFM	45,021	49,007	47,313	47,113
Flow rate - DSCF/ton	102,088	111,127	107,285	106,832
Temperature - °F	85	79	78	81
Water vapor - Vol. %	5.18	4.97	5.10	5.08
CO_2 - Vol. % dry	0.6	0.6	0.6	0.6
O_2 - Vol. % dry	20.2	20.2	20.2	20.2
CO - Vol. % dry	0.0	0.0	0.0	0.0
Visible Emissions - % opacity	10%	10%	10%	10%
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0016	0.0052	0.0027	0.0032
gr/ACF	0.0015	0.0049	0.0026	0.0030
lb/hr	0.615	2.200	1.111	1.308
lb/ton of product	1.39	4.98	2.52	2.96
Total Catch				
gr/DSCF	0.0037	0.0094	0.0062	0.0064
gr/ACF	0.0034	0.0088	0.0058	0.0060
lb/hr	1.415	3.937	2.528	2.63
lb/ton of product	3.21	8.91	5.74	5.95

Table 7A-6a

FACILITY - F (Primary Inlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	9/27/71	9/28/71	9/28/71	
Test Time-minutes	64	64	64	64
Production rate - TPH	0.544	0.544	0.544	0.544
Stack Effluent				
Flow rate - DSCFM	7040	6920	6780	6913
Flow rate - DSCF/ton	15,679	15,412	15,100	15,396
Temperature - °F	271	281	308	287
Water vapor - Vol. %	2.8	3.1	2.7	2.8
CO_2 - Vol. % dry	5.03	4.63	4.63	4.76
O_2 - Vol. % dry	16.03	17.83	17.83	17.23
CO - Vol. % dry	NS	NS	NS	NS
Visible Emissions - % opacity	NA	NA	NA	NA
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.250	0.299	0.234	0.261
gr/ACF	0.178	0.210	0.159	0.182
lb/hr	15.10	17.70	13.60	15.46
lb/ton of product	27.80	32.55	25.05	28.46
Total Catch				
gr/DSCF	0.323	0.360	0.302	0.328
gr/ACF	0.299	0.253	0.205	0.252
lb/hr	19.70	21.40	17.60	19.56
lb/ton of product	36.25	39.35	32.35	35.98

Table 7A-6b

FACILITY - F (Primary Outlet - Particulates

Summary of Results

Run number	1	2	3	Average
Date	2/27/71	9/28/71	9/28/71	
Test Time-minutes	112	112	112	112
Production rate - TPH	0.544	0.544	0.544	0.544
Stack Effluent				
Flow rate - DSCFM	6440	6750	6240	6744
Flow rate - DSCF/ton	11,838	12,408	11,470	11,906
Temperature - °F	88	87	98	91
Water vapor - Vol. %	9.7	5.4	6.1	7.1
CO_2 - Vol. % dry	3.67	4.20	4.20	4.02
O_2 - Vol. % dry	18.50	18.10	18.10	18.23
CO - Vol. % dry	NS	NS	NS	NS
Visible Emissions - % opacity	0-10	0-10	0-10	0-10
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00285	0.00225	0.00186	0.00232
gr/ACF	0.00251	0.00208	0.00167	0.00208
lb/hr	0.155	0.128	0.100	0.128
lb/ton of product	0.285	0.235	0.184	0.268
Total Catch				
gr/DSCF	0.01335	0.01019	0.01281	0.01211
gr/ACF	0.01174	0.00943	0.01152	0.0109
lb/hr	0.734	0.588	0.686	0.669
lb/ton of product	1.35	1.08	1.26	1.23

Table 7A-7a

FACILITY - G (ESP* Outlet - Particulates)

Summary of Results

Run number	1	2	3	Average
Date	6/20/72	6/21/72	6/21/72	
Test Time-minutes	224	140	140	168
Production rate - TPH (Anode)	9.1	9.1	9.1	9.1
Stack Effluent				
Flow rate - DSCFM	45,490	45,670	50,330	47,163
Flow rate - DSCF/ton	3,619	3,633	4,004	37,520
Temperature - °F	119	132	131	127
Water vapor - Vol. %	4.80	6.80	6.10	5.90
CO_2 - Vol. % dry	0.66	0.66	0.66	0.66
O_2 - Vol. % dry	14.30	14.30	14.30	14.30
CO - Vol. % dry	1.60	1.60	1.60	1.60
Visible Emissions - % opacity	10-20	10-20	10-20	10-20
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0176	0.0169	0.0172	0.0172
gr/ACF	0.0149	0.0138	0.0141	0.0143
lb/hr	6.85	6.63	7.42	6.97
lb/ton of anode	0.75	0.73	0.82	0.77
Total Catch				
gr/DSCF	0.0405	0.0324	0.0324	0.0351
gr/ACF	0.0344	0.0264	0.0266	0.0291
lb/hr	15.80	12.70	13.98	14.16
lb/ton of anode	1.74	1.40	1.54	1.56

* Electrostatic Precipitator

Table 7A-7b

FACILITY - G (ESP* Outlet - Fluorides)

Summary of Results

Run number	1	2	3	Average
Date	6/20/72	6/21/72	6/21/72	
Test Time-minutes	224	140	140	168
Production rate - TPH (Anode)	9.1	9.1	9.1	9.1
Stack Effluent				
Flow rate - DSCFM	38,830	44,620	37,060	39,503
Flow rate - DSCF/ton	2,930	3,550	2,950	3,143
Temperature - °F	117.3	125.2	125.1	122.5
Water vapor - Vol. %	7.52	7.36	6.46	7.11
CO_2 - Vol. % dry	0.66	0.66	0.66	0.66
O_2 - Vol. % dry	14.3	14.3	14.3	14.3
CO - Vol. % dry	1.6	1.6	1.6	1.6
Visible Emissions - % opacity	20	20	20	20
Fluorides				
Soluble				
gr/DSCF	0.0182	0.0211	0.0206	0.0200
gr/ACF	0.0150	0.0173	0.0170	0.0164
lb/hr	5.75	8.06	6.54	6.78
lb/ton of anode	0.63	0.89	0.72	0.74
Total Fluorides				
gr/DSCF	0.0201	0.0221	0.0216	0.0213
gr/ACF	0.0166	0.0183	0.0179	0.0176
lb/hr	6.35	8.69	8.87	7.97
lb/ton of anode	0.70	0.96	0.98	0.88

* Electrostatic Precipitator

Table 7A-8

FACILITY - H (Anode Furnace - ESP*)

Summary of Results

Run number	1	2	3	Average
Date	10/19/72	10/19/72	10/20/72	
Test Time-minutes	240	240	240	240
Production rate - TPH (Anode)	13.15	13.15	13.15	13.15
Stack Effluent				
Flow rate - DSCFM	75,774	72,460	70,340	72,858
Flow rate - DSCF/ton	5,762	5,510	5,349	5,540
Temperature - °F	196	215	206	
Water vapor - Vol. %	3.5	3.7	3.2	3.5
CO_2 - Vol. % dry	1.1	1.1	1.1 1/	1.1
O_2 - Vol. % dry	19.1	19.1	19.1 1/	19.1
CO - Vol. % dry	0.0	0.0	0.0 1/	0.0
Visible Emissions - % opacity	10-20%	10-20%	10-20%	10-20%
Fluorides				
Soluble				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				
Total Fluorides				
gr/DSCF	0.02555	0.02708	0.02605	0.02627
gr/ACF	0.02002	0.02056	0.02027	0.02019
lb/hr	16.58	16.81	15.69	16.36
lb/ton of anode	1.26	1.28	1.20	1.25

* Electrostatic Precipitator
1/ ORSAT analyzer was not operating properly. This data questionable.

Appendix 8A

Emission Flow Diagrams

The following figures present the quantities of solid F, gaseous F, total F, and alumina appearing in each of the several process streams of the emission control systems represented by various models considered in the cost effectiveness analysis. Quantities are expressed in terms of pounds per 1000 pounds of aluminum produced, and are derived from the effluent model parameters given in Table 8.1. The removal efficiencies for control are derived from data given in Section 5.

These model flow diagrams represent performances which are characteristic of the best aluminum potline emission control with the equipment noted, and which may be better than conditions obtained in any specific plant. Variation in the designs of hooding and collection systems, in the design and construction of removal equipment, and in the operations of potlines and control systems will result in departure from the predicted emission control of the model.

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL:1A-1 PREBAKE
OVERALL CONTROL EFFICIENCY: 94.6 %

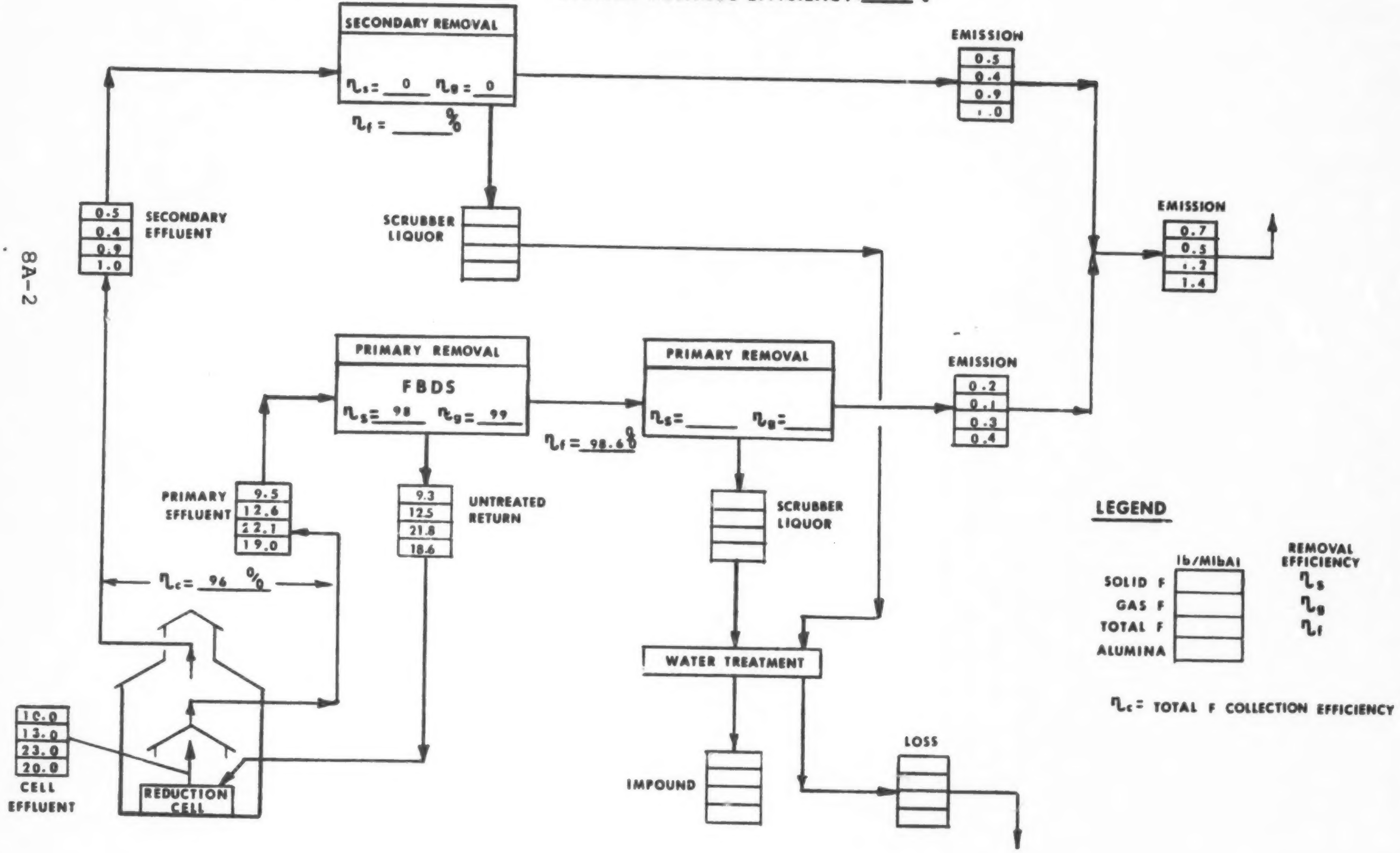

SECONDARY REMOVAL
ηs = 0 ηg = 0
ηf = %
EMISSION
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
EMISSION
0.7
0.5
1.2
1.4
PRIMARY REMOVAL
FBDS
ηs = 98 ηg = 99
ηf = 98.6 %
PRIMARY REMOVAL
ηs = ηg =
EMISSION
0.2
0.1
0.3
0.4
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
9.3
12.5
21.8
18.6
SCRUBBER LIQUOR
ηc = 96 %
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
LOSS
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F ηs
GAS F ηg
TOTAL F ηf
ALUMINA
ηc = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: 1A-2 PREBAKE
OVERALL CONTROL EFFICIENCY: 93.8 %

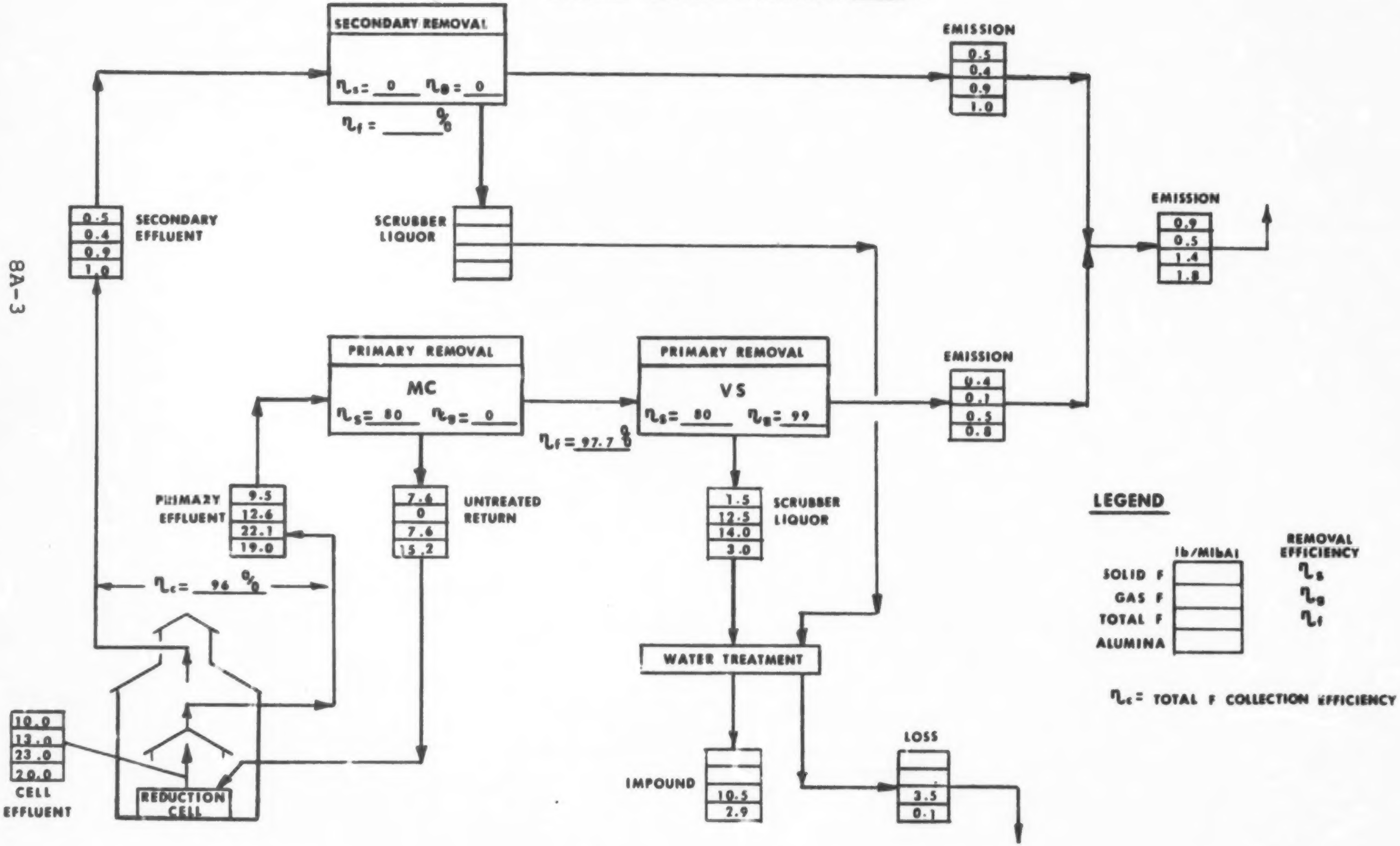

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = ____ %
EMISSION
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
EMISSION
0.9
0.5
1.4
1.8
PRIMARY REMOVAL
MC
η_s = 80 η_g = 0
PRIMARY REMOVAL
VS
η_s = 80 η_g = 99
η_f = 97.7 %
EMISSION
0.4
0.1
0.5
0.8
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
7.6
0
7.6
15.2
SCRUBBER LIQUOR
1.5
12.5
14.0
3.0
η_c = 96 %
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
10.5
2.9
LOSS
3.5
0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL:1A-3 FREBAKE
OVERALL CONTROL EFFICIENCY: 92.1 %

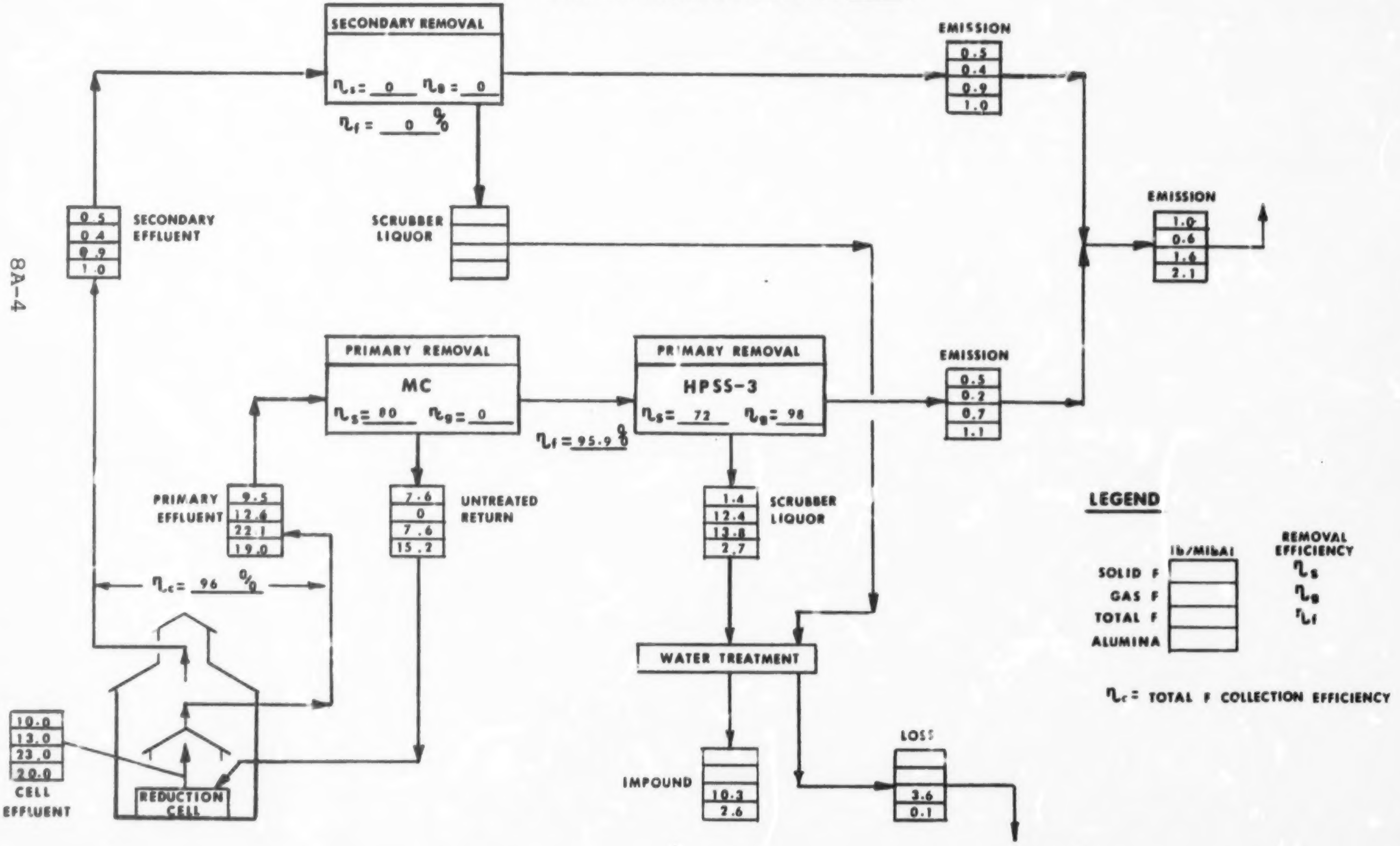

SECONDARY REMOVAL
$\eta_s = 0$ $\eta_g = 0$
$\eta_f = 0$ %
EMISSION
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
EMISSION
1.0
0.6
1.6
2.1
PRIMARY REMOVAL
MC
$\eta_s = 80$ $\eta_g = 0$
PRIMARY REMOVAL
HPSS-3
$\eta_s = 72$ $\eta_g = 98$
$\eta_f = 95.9$ %
EMISSION
0.5
0.2
0.7
1.1
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
7.6
0
7.6
15.2
SCRUBBER LIQUOR
1.4
12.4
13.8
2.7
$\eta_c = 96$ %
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
10.3
2.6
LOSS
3.6
0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IA-4 PREBAKE
OVERALL CONTROL EFFICIENCY: 92.4 %

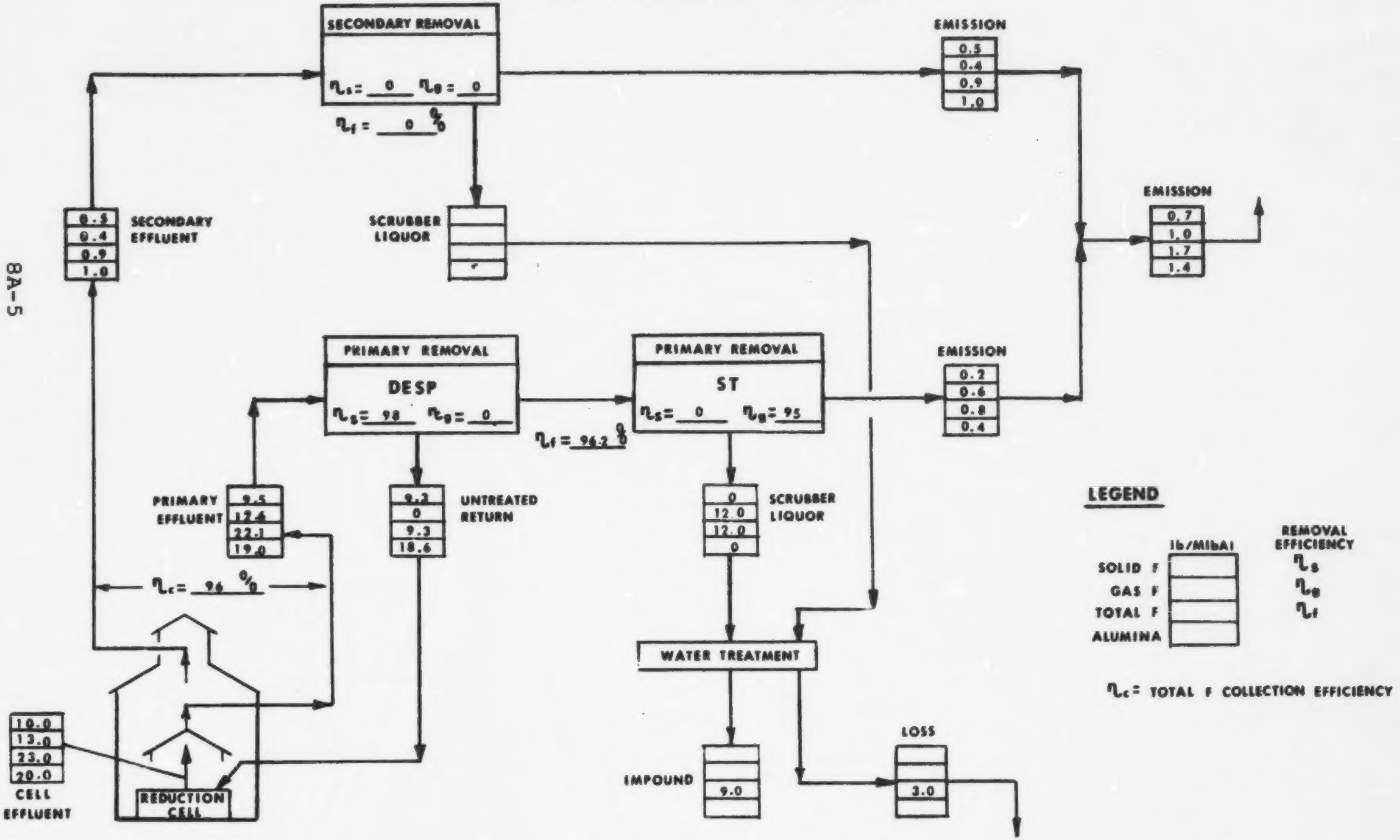

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
EMISSION
0.7
1.0
1.7
1.4
PRIMARY REMOVAL
DESP
η_s = 98 η_g = 0
PRIMARY REMOVAL
ST
η_s = 0 η_g = 95
η_f = 96.2 %
EMISSION
0.2
0.6
0.8
0.4
PRIMARY EFFLUENT
9.5
12.4
22.1
19.0
UNTREATED RETURN
9.3
0
9.3
18.6
SCRUBBER LIQUOR
0
12.0
12.0
0
η_c = 96 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
9.0
LOSS
3.0
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: 1A-5 PREBAKE
OVERALL CONTROL EFFICIENCY: 89.6 %

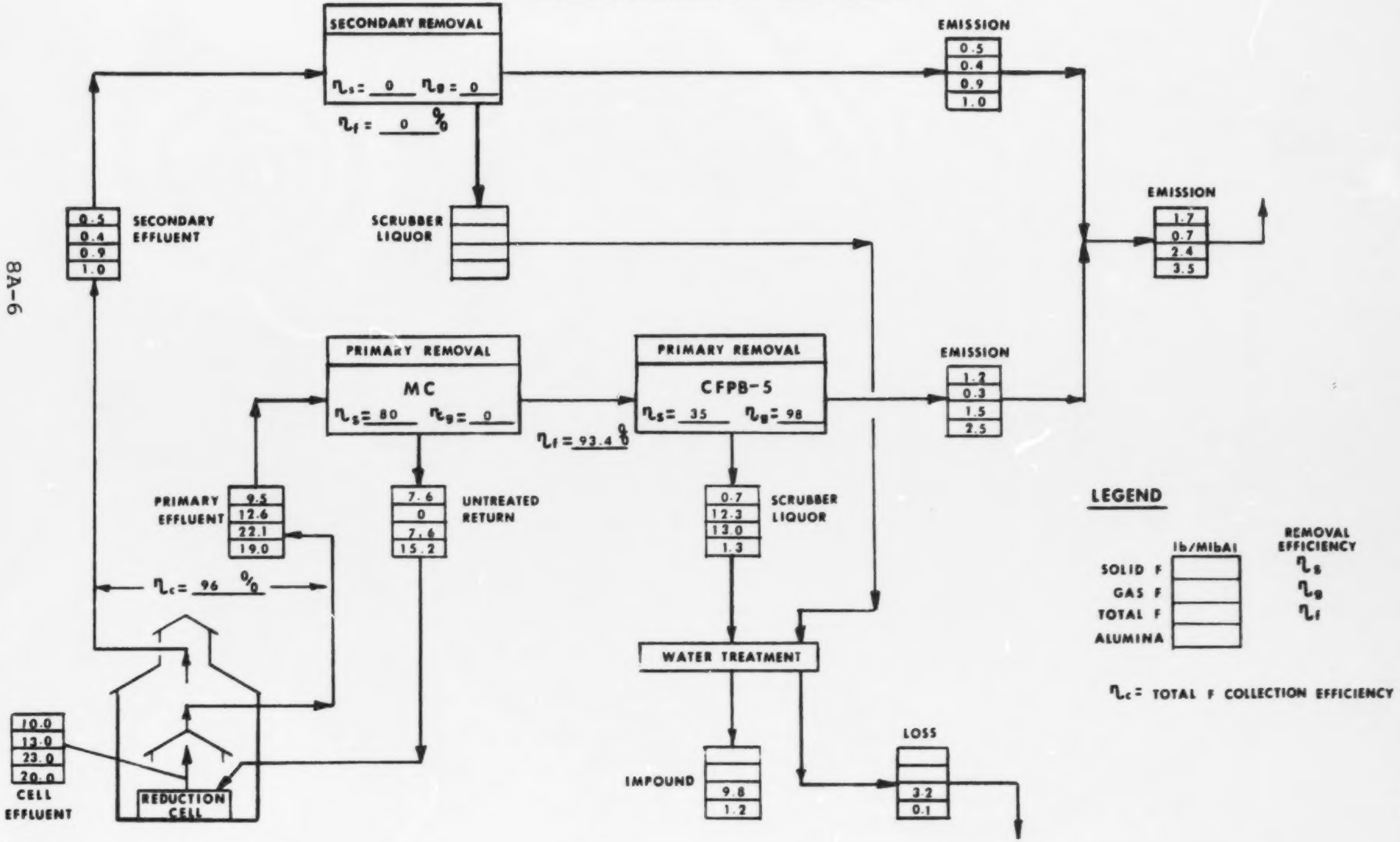

SECONDARY REMOVAL
ηs = 0 ηg = 0
ηf = 0 %
EMISSION
0.5
0.4
0.9
1.0
EMISSION
1.7
0.7
2.4
3.5
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
PRIMARY REMOVAL
MC
ηs = 80 ηg = 0
ηf = 93.4 %
PRIMARY REMOVAL
CFPB-5
ηs = 35 ηg = 98
EMISSION
1.2
0.3
1.5
2.5
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
7.6
0
7.6
15.2
SCRUBBER LIQUOR
0.7
12.3
13.0
1.3
ηc = 96 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
9.8
1.2
LOSS
3.2
0.1
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F ηs
GAS F ηg
TOTAL F ηf
ALUMINA
ηc = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: 1A-6 PREBAKE
OVERALL CONTROL EFFICIENCY: 85.2 %

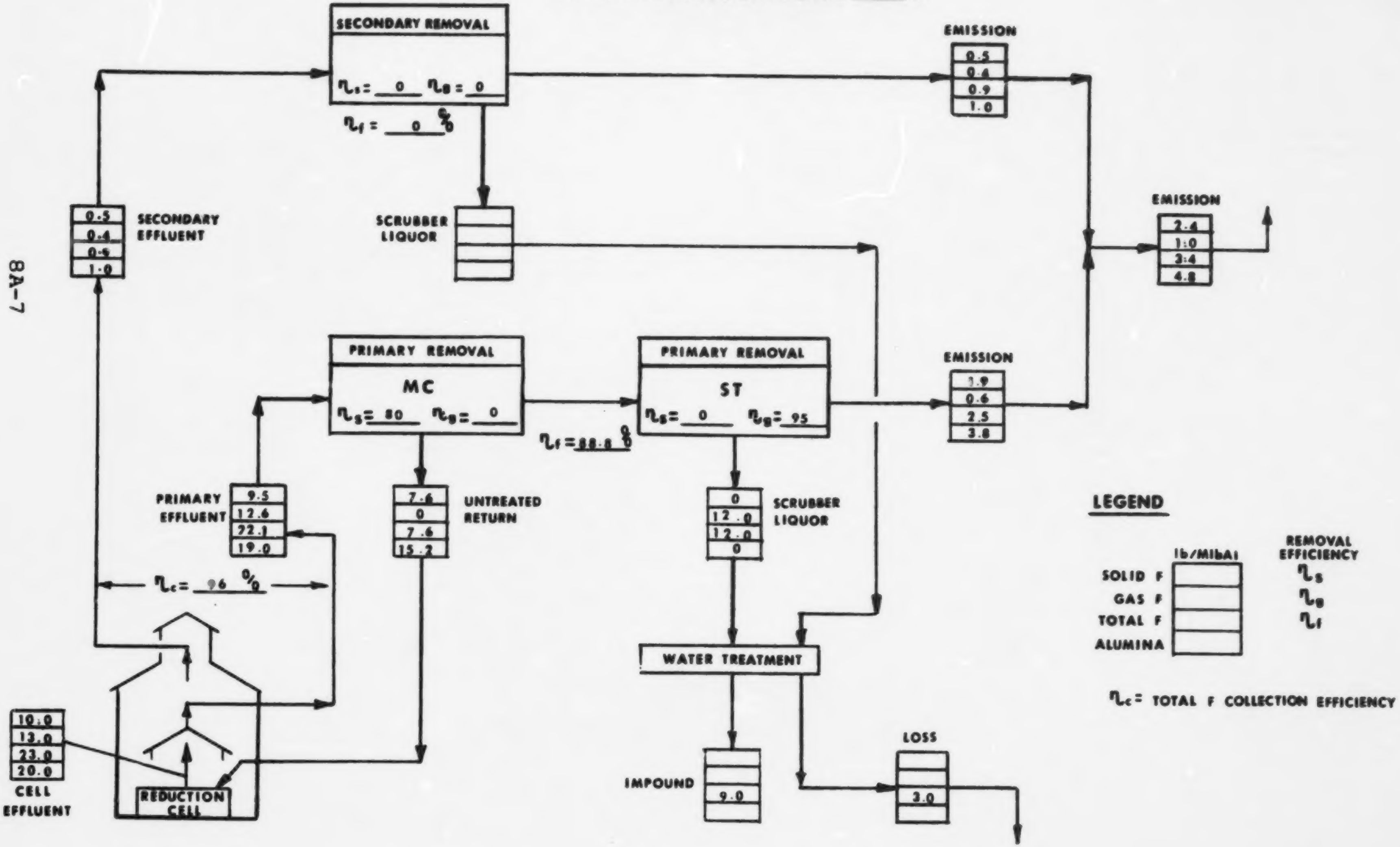

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
EMISSION
2.4
1.0
3.4
4.8
PRIMARY REMOVAL
MC
η_s = 80 η_g = 0
η_f = 88.8 %
PRIMARY REMOVAL
ST
η_s = 0 η_g = 95
EMISSION
1.9
0.6
2.5
3.8
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
7.6
0
7.6
15.2
SCRUBBER LIQUOR
0
12.0
12.0
0
η_c = 96 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
9.0
LOSS
3.0
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: 1B-1,9 PREBAKE
OVERALL CONTROL EFFICIENCY: 96.5 %

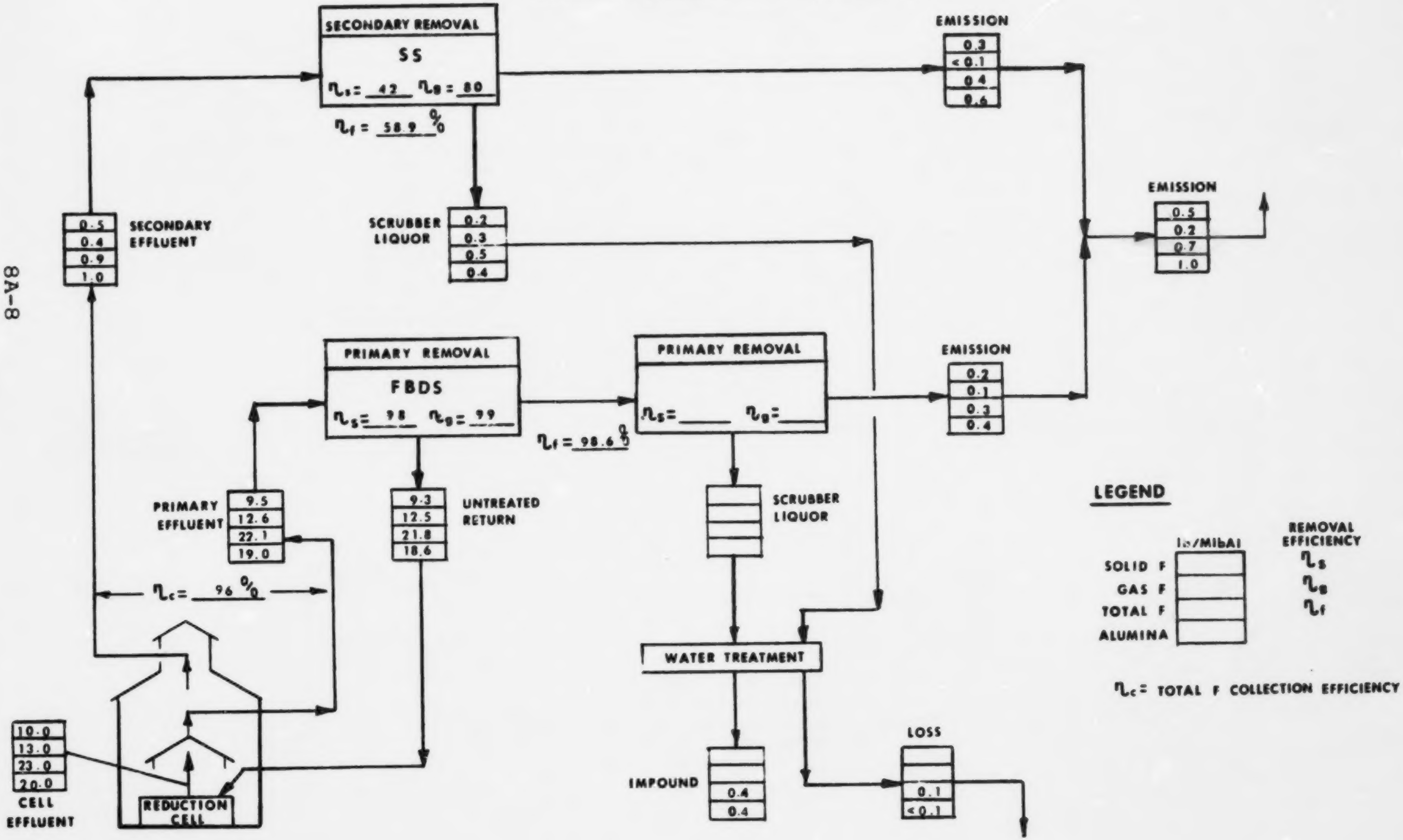

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 58.9 %
EMISSION
0.3
<0.1
0.4
0.6
EMISSION
0.5
0.2
0.7
1.0
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
0.2
0.3
0.5
0.4
PRIMARY REMOVAL
FBDS
η_s = 98 η_g = 99
η_f = 98.6 %
PRIMARY REMOVAL
η_s = η_g =
EMISSION
0.2
0.1
0.3
0.4
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
9.3
12.5
21.8
18.6
SCRUBBER LIQUOR
η_c = 96 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
0.4
0.4
LOSS
0.1
<0.1
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: 1B-29 PREBAKE
OVERALL CONTROL EFFICIENCY: 95.7 %

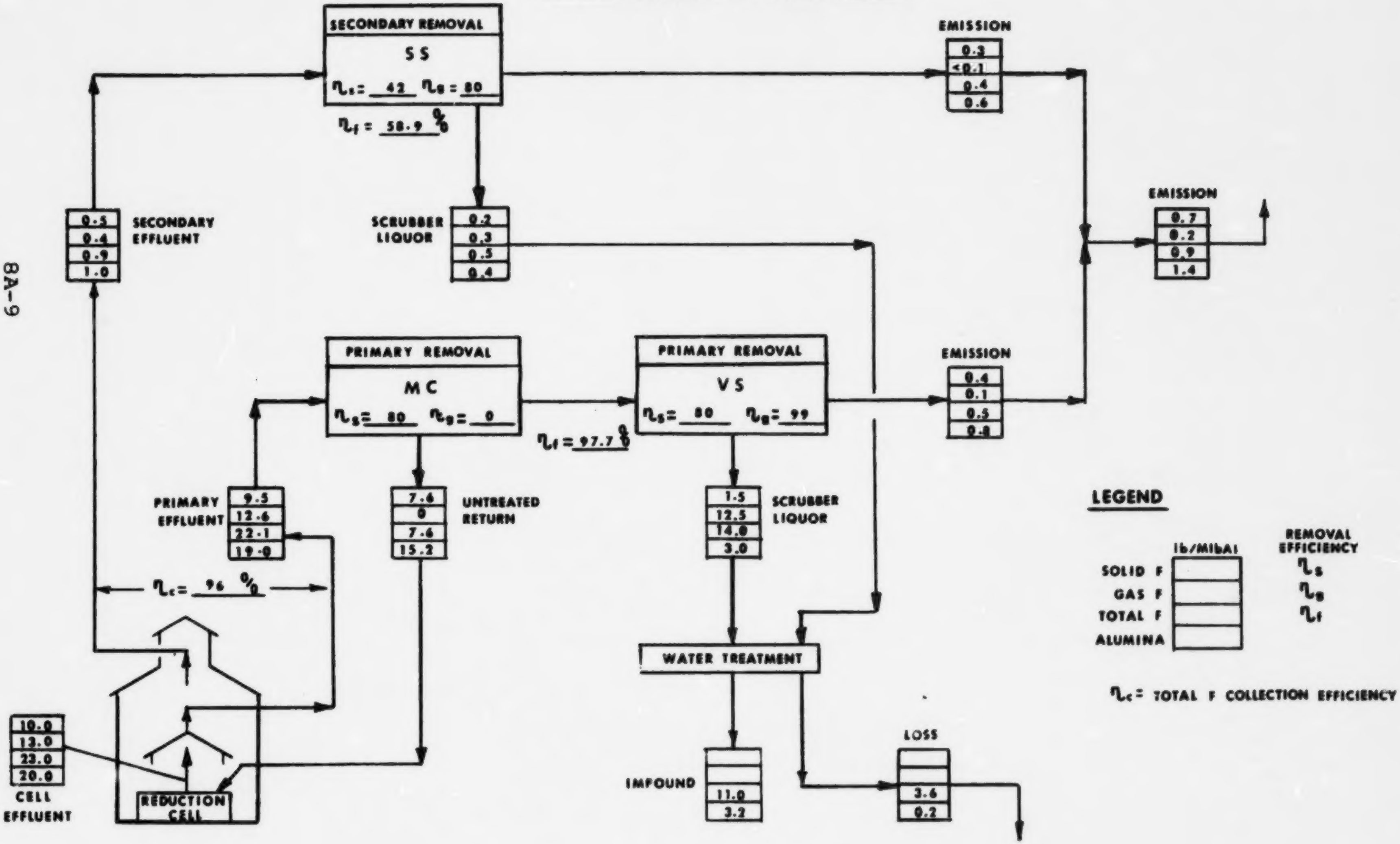

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 58.9 %
EMISSION
0.3
<0.1
0.4
0.6
EMISSION
0.7
0.2
0.9
1.4
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
0.2
0.3
0.5
0.4
PRIMARY REMOVAL
MC
η_s = 80 η_g = 0
η_f = 97.7 %
PRIMARY REMOVAL
VS
η_s = 80 η_g = 99
EMISSION
0.4
0.1
0.5
0.8
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
7.6
0
7.6
15.2
SCRUBBER LIQUOR
1.5
12.5
14.0
3.0
η_c = 96 %
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
11.0
3.2
LOSS
3.6
0.2
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IB-39 PREBAKE
OVERALL CONTROL EFFICIENCY: 94.0 %

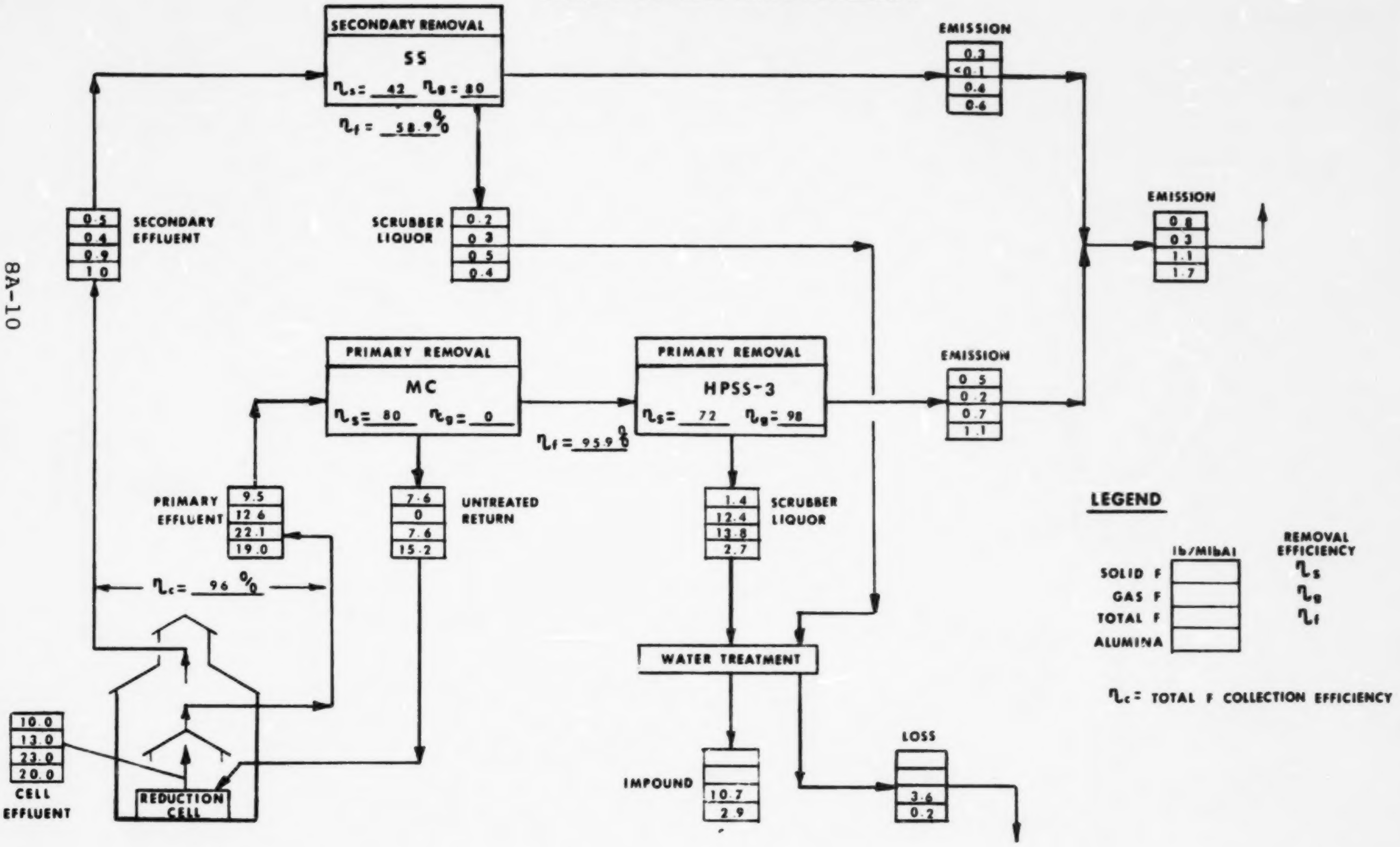

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 58.9 %
EMISSION
0.3
<0.1
0.4
0.6
EMISSION
0.8
0.3
1.1
1.7
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
0.2
0.3
0.5
0.4
PRIMARY REMOVAL
MC
η_s = 80 η_g = 0
PRIMARY REMOVAL
HPSS-3
η_s = 72 η_g = 98
η_f = 95.9 %
EMISSION
0.5
0.2
0.7
1.1
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
7.6
0
7.6
15.2
SCRUBBER LIQUOR
1.4
12.4
13.8
2.7
η_c = 96 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
10.7
2.9
LOSS
3.6
0.2
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IB-4,9 PREBAKE
OVERALL CONTROL EFFICIENCY: 94.3 %

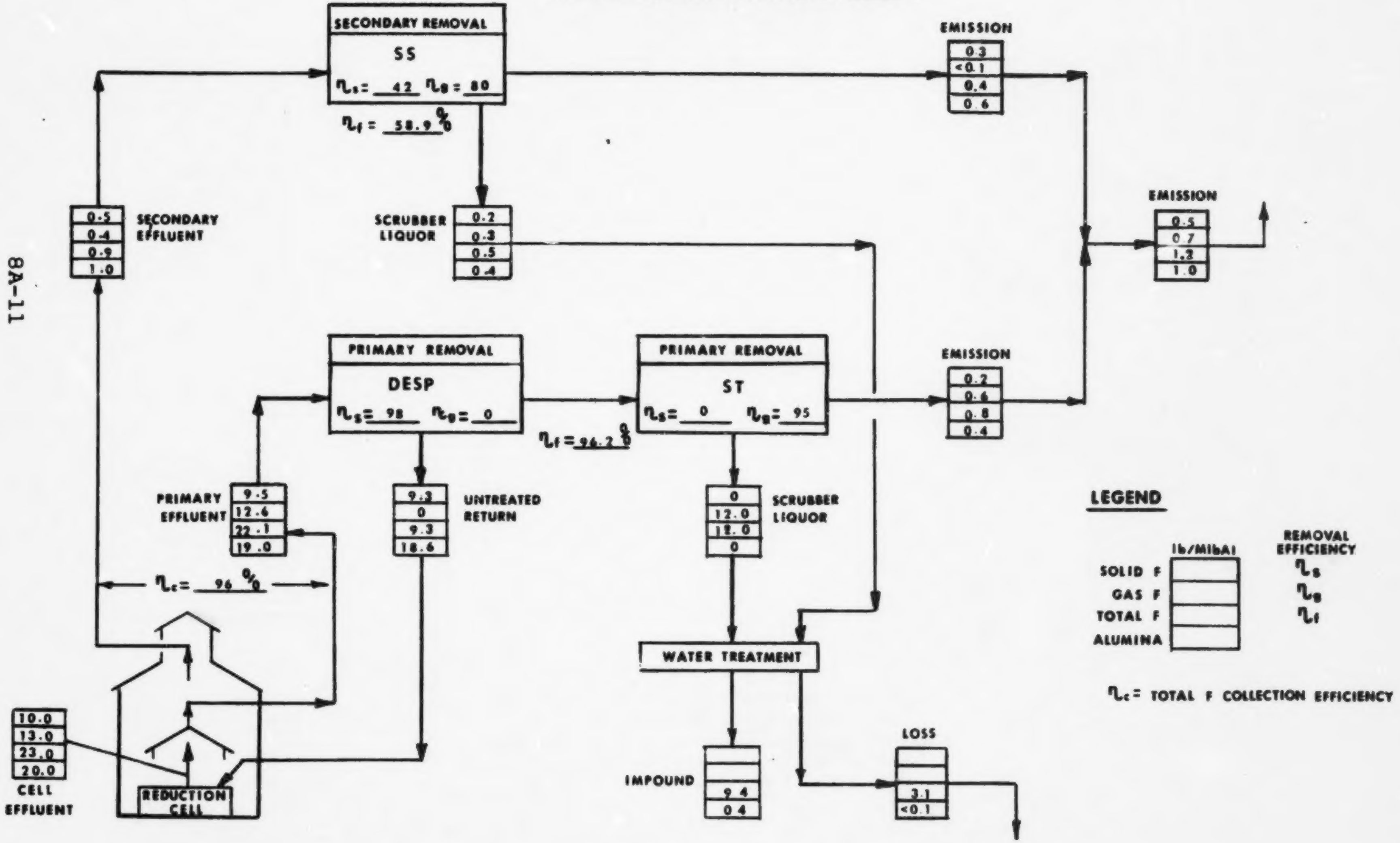

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 58.9 %
EMISSION
0.3
<0.1
0.4
0.6
SECONDARY EFFLUENT
0.5
0.4
0.9
1.0
SCRUBBER LIQUOR
0.2
0.3
0.5
0.4
EMISSION
0.5
0.7
1.2
1.0
PRIMARY REMOVAL
DESP
η_s = 98 η_g = 0
PRIMARY REMOVAL
ST
η_s = 0 η_g = 95
η_f = 96.2 %
EMISSION
0.2
0.6
0.8
0.4
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
UNTREATED RETURN
9.3
0
9.3
18.6
SCRUBBER LIQUOR
0
12.0
12.0
0
η_c = 96 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
9.4
0.4
LOSS
3.1
<0.1
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IB-5,9 PREBAKE
OVERALL CONTROL EFFICIENCY: 91.5 %

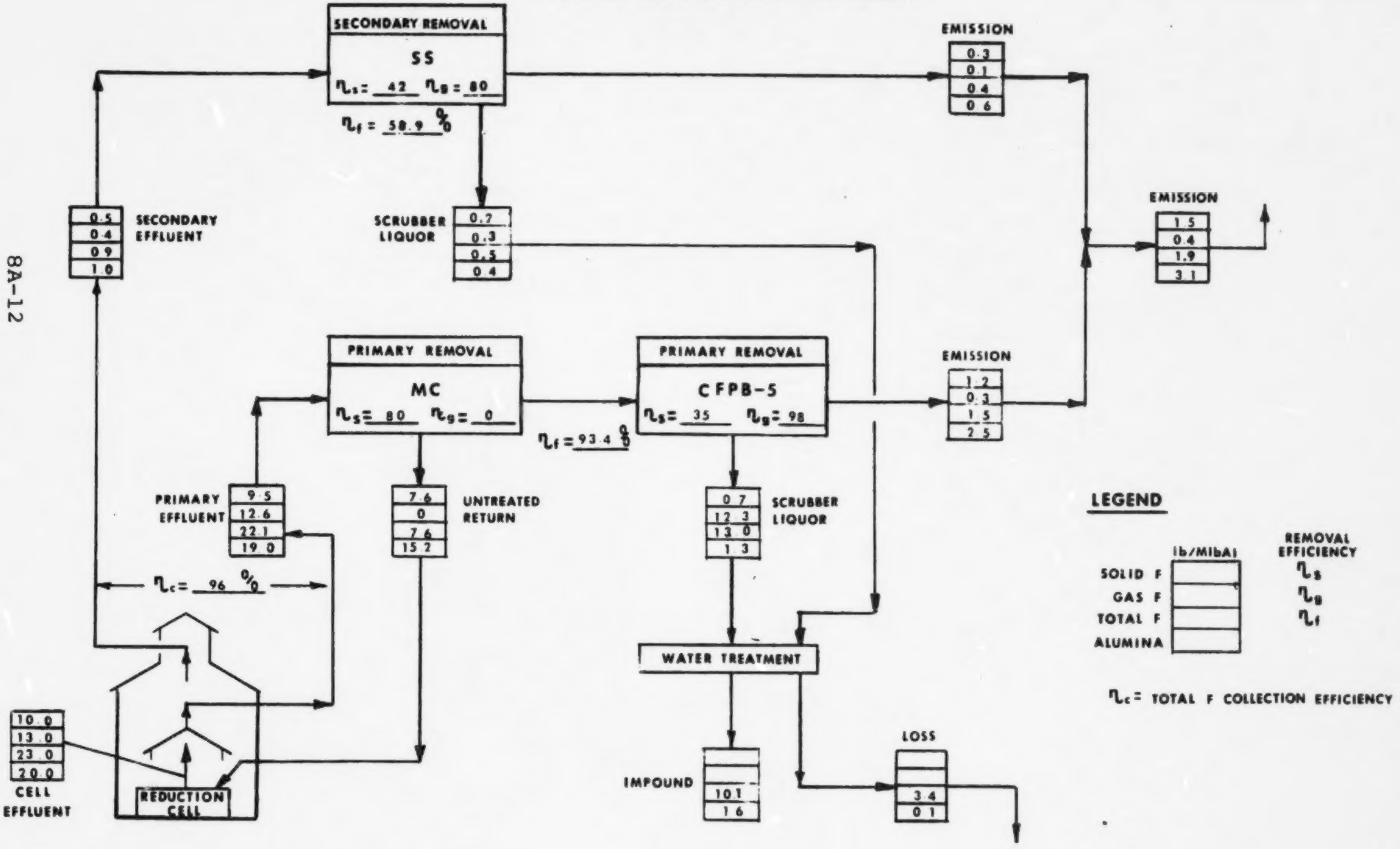

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 58.9 %
EMISSION
0.3
0.1
0.4
0.6
EMISSION
1.5
0.4
1.9
3.1
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
SCRUBBER LIQUOR
0.2
0.3
0.5
0.4
PRIMARY REMOVAL
MC
η_s = 80 η_g = 0
PRIMARY REMOVAL
CFPB-5
η_s = 35 η_g = 98
η_f = 93.4 %
EMISSION
1.2
0.3
1.5
2.5
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
7.6
0
7.6
15.2
UNTREATED RETURN
0.7
12.3
13.0
1.3
SCRUBBER LIQUOR
η_c = 96 %
WATER TREATMENT
10.0
13.0
23.0
20.0
CELL EFFLUENT
REDUCTION CELL
IMPOUND
10.1
1.6
LOSS
3.4
0.1
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IB-6,9 PREBAKE
OVERALL CONTROL EFFICIENCY: 87.1 %

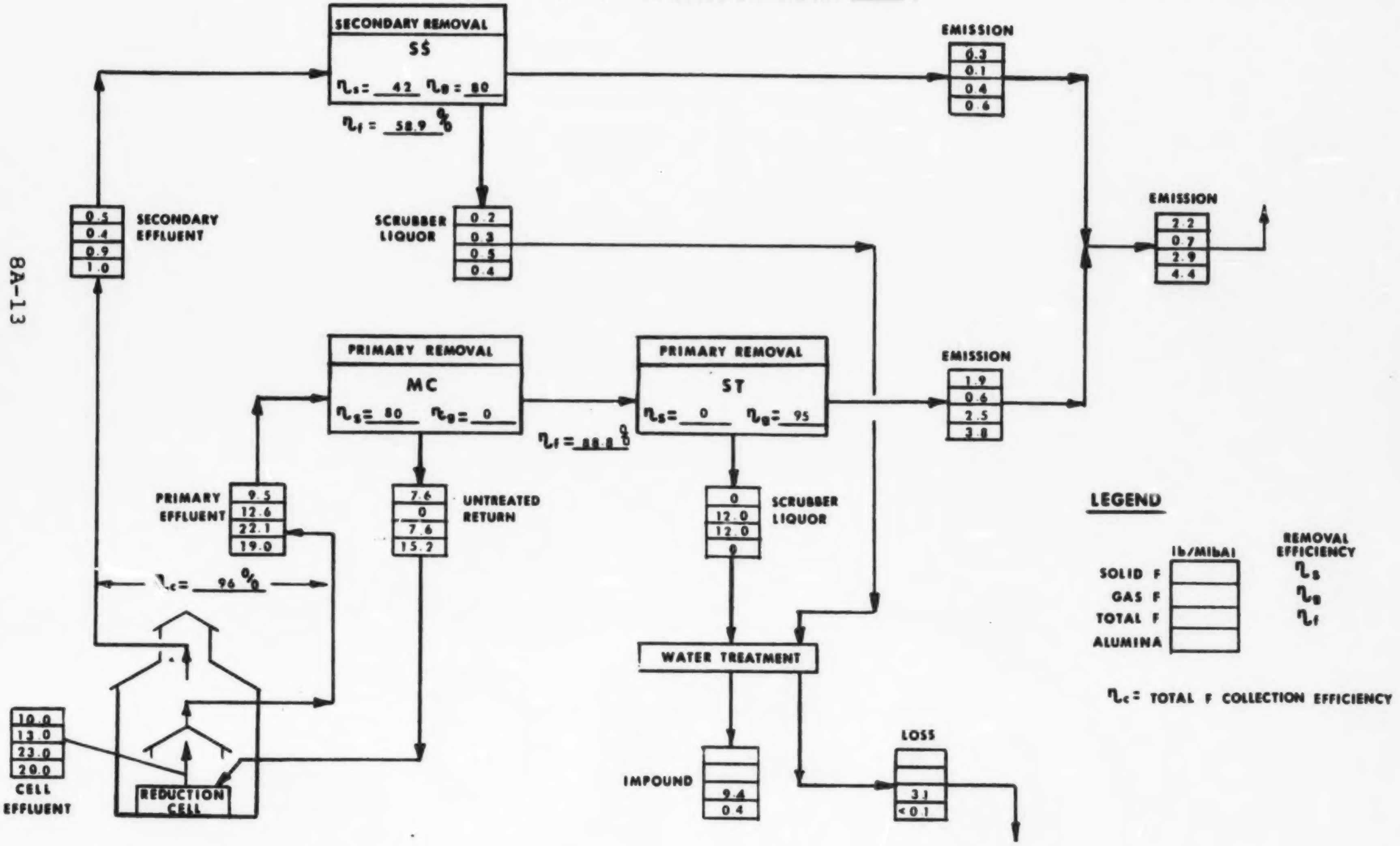

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 58.9 %
EMISSION
0.3
0.1
0.4
0.6
EMISSION
2.2
0.7
2.9
4.4
0.5
0.4
0.9
1.0
SECONDARY EFFLUENT
SCRUBBER LIQUOR
0.2
0.3
0.5
0.4
PRIMARY REMOVAL
MC
η_s = 80 η_g = 0
PRIMARY REMOVAL
ST
η_s = 0 η_g = 95
η_f = 88.8 %
EMISSION
1.9
0.6
2.5
3.8
PRIMARY EFFLUENT
9.5
12.6
22.1
19.0
7.6
0
7.6
15.2
UNTREATED RETURN
0
12.0
12.0
0
SCRUBBER LIQUOR
η_c = 96 %
WATER TREATMENT
10.0
13.0
23.0
20.0
CELL EFFLUENT
REDUCTION CELL
IMPOUND
9.4
0.4
LOSS
3.1
< 0.1
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F
GAS F
TOTAL F
ALUMINA
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II A-1VSS SODERBERG
OVERALL CONTROL EFFICIENCY: 79.6 %

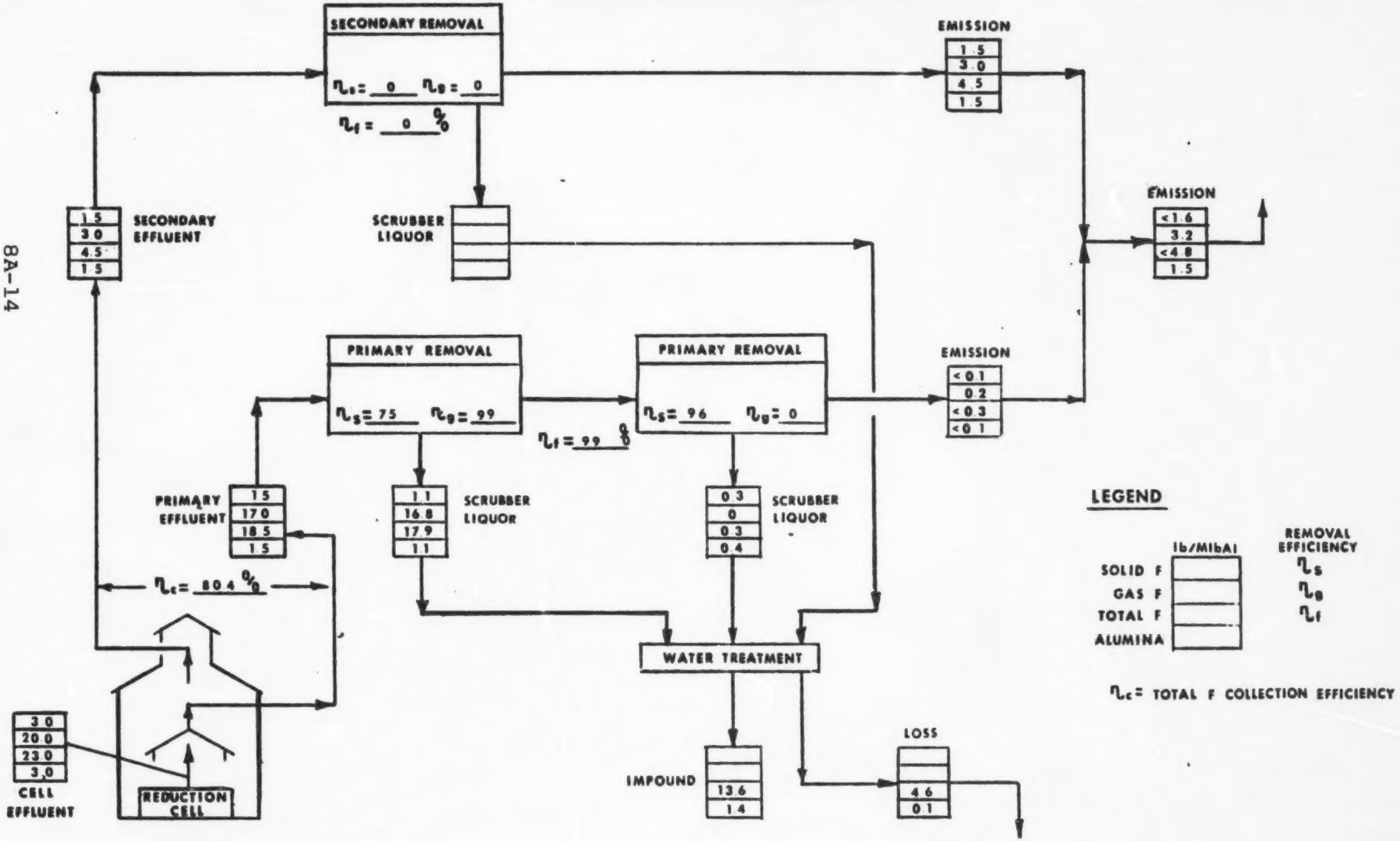

SECONDARY REMOVAL
η_s = 0
η_g = 0
η_f = 0 %
EMISSION
1.5
3.0
4.5
1.5
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
EMISSION
<1.6
3.2
<4.8
1.5
PRIMARY REMOVAL
η_s = 75
η_g = 99
η_f = 99 %
PRIMARY REMOVAL
η_s = 96
η_g = 0
EMISSION
<0.1
0.2
<0.3
<0.1
PRIMARY EFFLUENT
15
17.0
18.5
1.5
SCRUBBER LIQUOR
1.1
16.8
17.9
1.1
SCRUBBER LIQUOR
0.3
0
0.3
0.4
η_c = 80.4 %
WATER TREATMENT
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
IMPOUND
13.6
1.4
LOSS
4.6
0.1
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F
GAS F
TOTAL F
ALUMINA
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II A-2 VSS SODERBERG
OVERALL CONTROL EFFICIENCY: 79.5 %

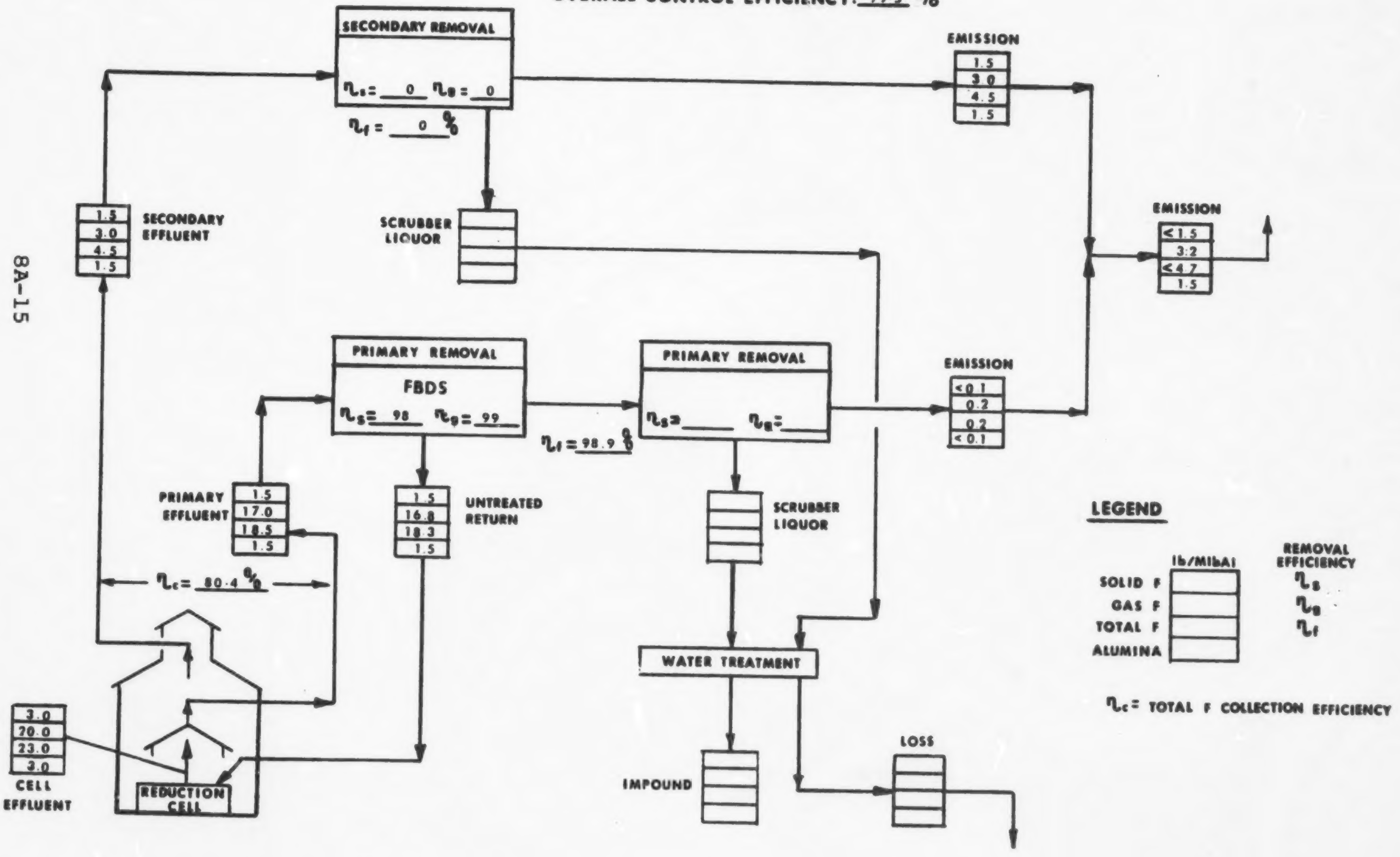

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
1.5
3.0
4.5
1.5
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
EMISSION
<1.5
3.2
<4.7
1.5
PRIMARY REMOVAL
FBDS
η_s = 98 η_g = 99
η_f = 98.9 %
PRIMARY REMOVAL
η_s = η_g =
EMISSION
<0.1
0.2
0.2
<0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
1.5
16.8
18.3
1.5
SCRUBBER LIQUOR
η_c = 80.4 %
WATER TREATMENT
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
IMPOUND
LOSS
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IIA-3 VSS SODERBERG
OVERALL CONTROL EFFICIENCY: 79.5 %

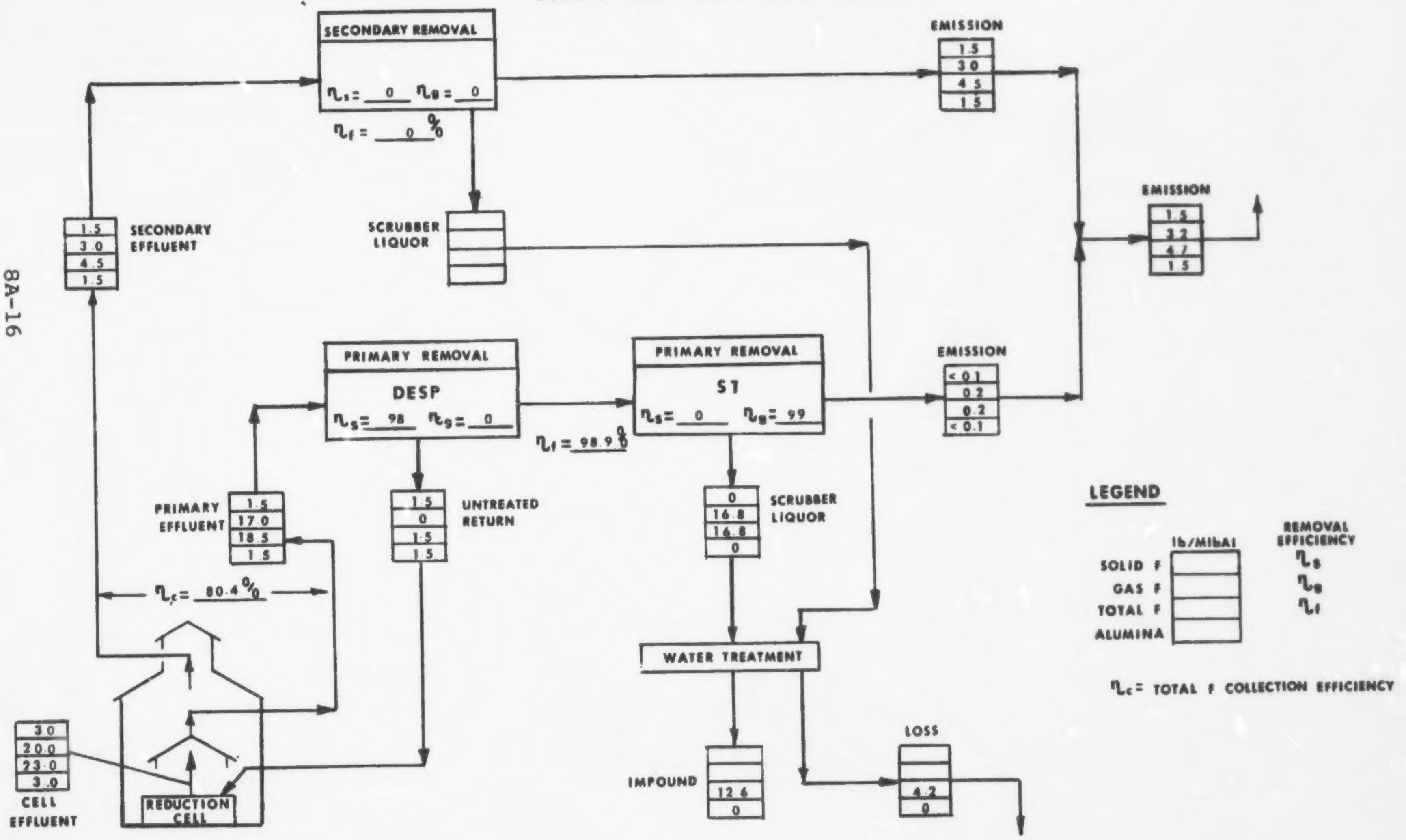

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
1.5
3.0
4.5
1.5
EMISSION
1.5
3.2
4.7
1.5
1.5
3.0
4.5
1.5
SECONDARY EFFLUENT
SCRUBBER LIQUOR
PRIMARY REMOVAL
DESP
η_s = 98 η_g = 0
PRIMARY REMOVAL
ST
η_s = 0 η_g = 99
η_f = 98.9 %
EMISSION
< 0.1
0.2
0.2
< 0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
1.5
0
1.5
1.5
UNTREATED RETURN
0
16.8
16.8
0
SCRUBBER LIQUOR
η_c = 80.4 %
3.0
20.0
23.0
3.0
CELL EFFLUENT
REDUCTION CELL
WATER TREATMENT
IMPOUND
12.6
0
LOSS
4.2
0
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F
GAS F
TOTAL F
ALUMINA
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL:IIA-4 VSS SODERBERG
OVERALL CONTROL EFFICIENCY: 79.4 %

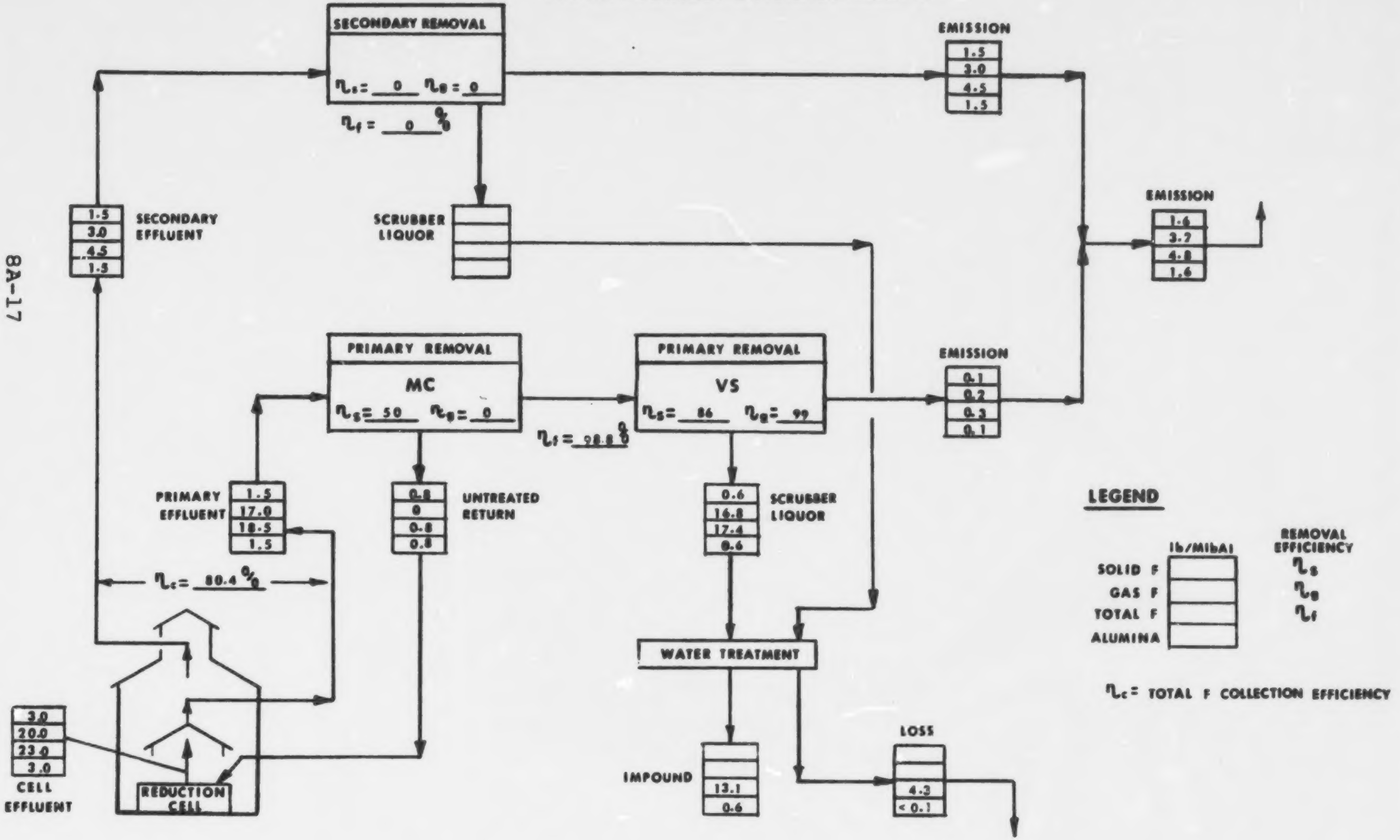

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
1.5
3.0
4.5
1.5
EMISSION
1.6
3.7
4.8
1.6
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
PRIMARY REMOVAL
MC
η_s = 50 η_g = 0
PRIMARY REMOVAL
VS
η_s = 86 η_g = 99
η_f = 98.8 %
EMISSION
0.1
0.2
0.3
0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
0.8
0
0.8
0.8
SCRUBBER LIQUOR
0.6
16.8
17.4
0.6
η_c = 80.4 %
WATER TREATMENT
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
IMPOUND
13.1
0.6
LOSS
4.3
< 0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL IIA-5 VSS SODERBERG
OVERALL CONTROL EFFICIENCY: 78.4 %

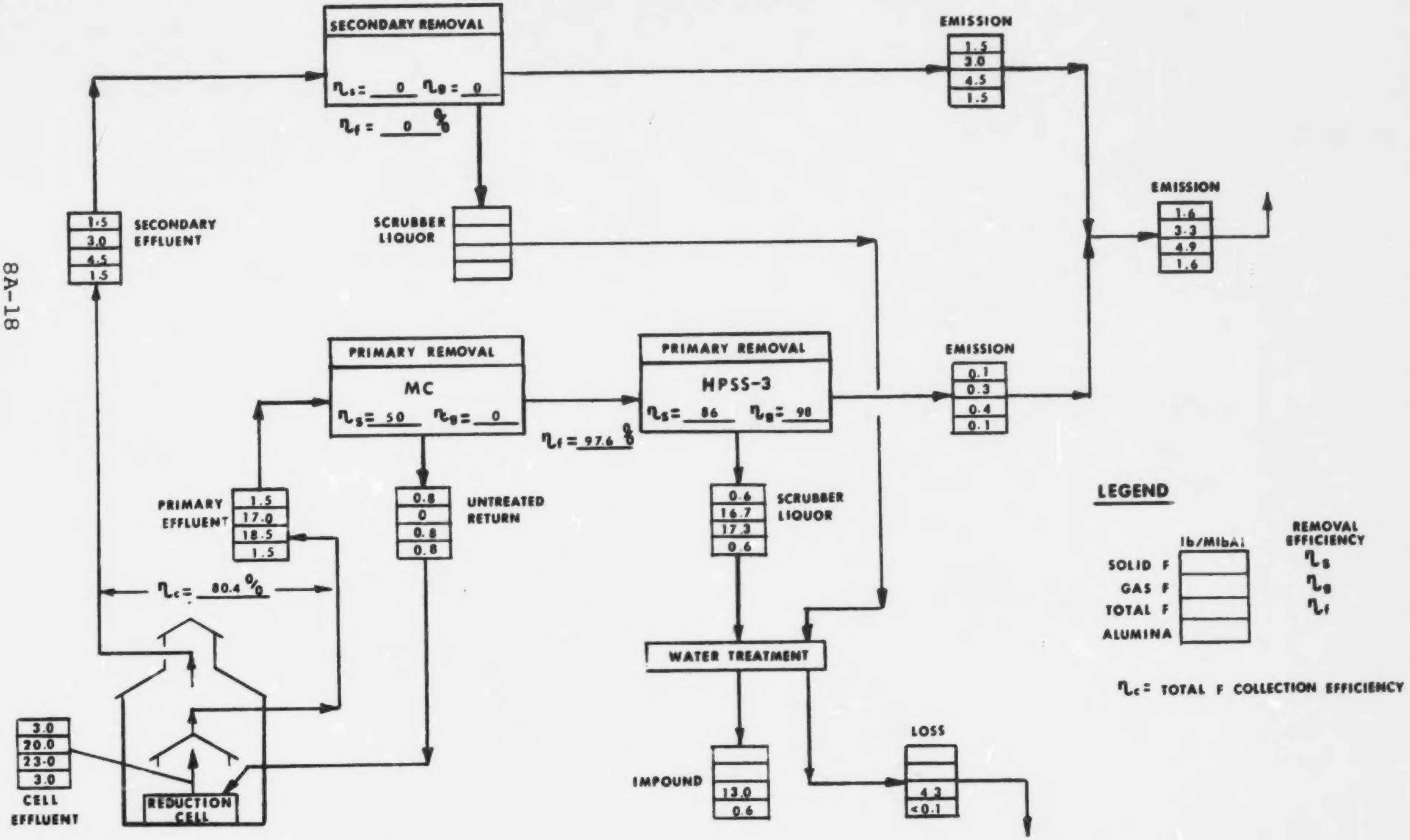

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
1.5
3.0
4.5
1.5
EMISSION
1.6
3.3
4.9
1.6
1.5
3.0
4.5
1.5
SECONDARY EFFLUENT
SCRUBBER LIQUOR
PRIMARY REMOVAL
MC
η_s = 50 η_g = 0
PRIMARY REMOVAL
HPSS-3
η_s = 86 η_g = 98
η_f = 97.6 %
EMISSION
0.1
0.3
0.4
0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
0.8
0
0.8
0.8
UNTREATED RETURN
0.6
16.7
17.3
0.6
SCRUBBER LIQUOR
η_c = 80.4 %
WATER TREATMENT
3.0
20.0
23.0
3.0
CELL EFFLUENT
REDUCTION CELL
IMPOUND
13.0
0.6
LOSS
4.3
<0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IIA-6 VSS SODERBERG
OVERALL CONTROL EFFICIENCY: 78.0 %

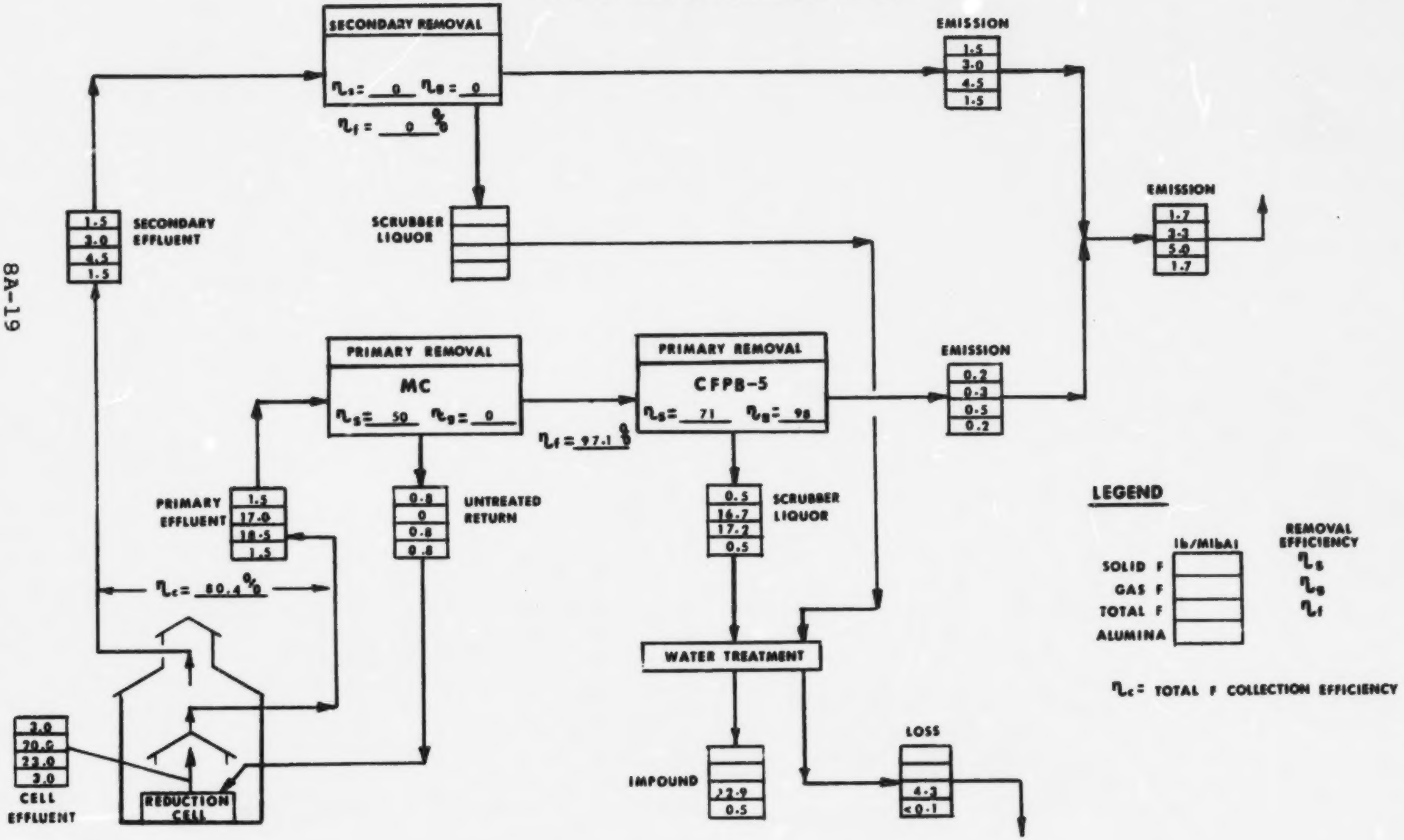

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
1.5
3.0
4.5
1.5
EMISSION
1.7
3.3
5.0
1.7
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
PRIMARY REMOVAL
MC
η_s = 50 η_g = 0
η_f = 97.1 %
PRIMARY REMOVAL
CFPB-5
η_s = 71 η_g = 98
EMISSION
0.2
0.3
0.5
0.2
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
0.8
0
0.8
0.8
SCRUBBER LIQUOR
0.5
16.7
17.2
0.5
η_c = 80.4 %
WATER TREATMENT
IMPOUND
12.9
0.5
LOSS
4.3
<0.1
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL

SYSTEM MODEL: IIB-1,7 VSS

OVERALL CONTROL EFFICIENCY: 93.8 %

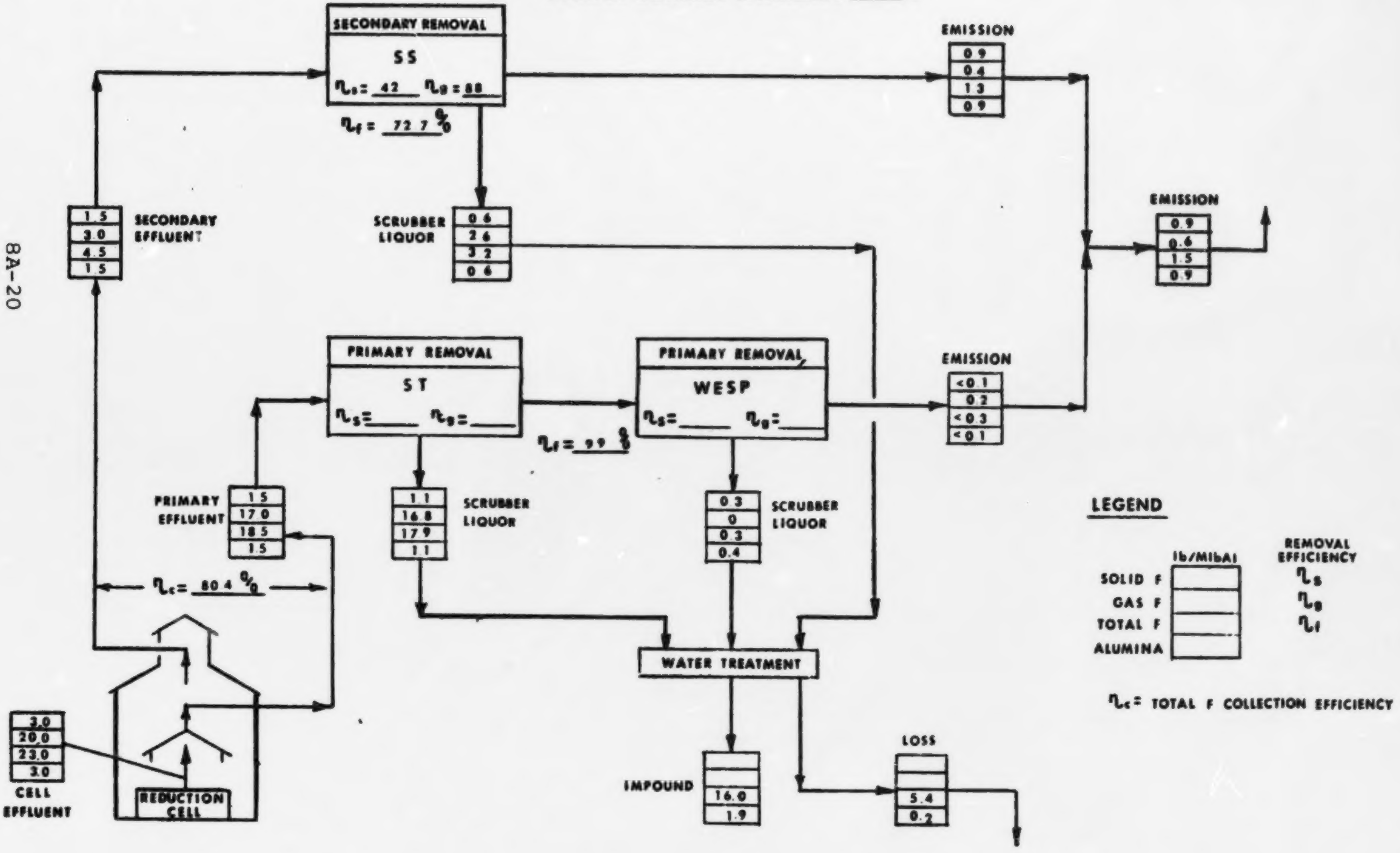

SECONDARY REMOVAL
SS
η_s = 42
η_g = 88
η_f = 72.7 %
EMISSION
0.9
0.4
1.3
0.9
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
0.6
2.6
3.2
0.6
EMISSION
0.9
0.6
1.5
0.9
PRIMARY REMOVAL
ST
η_s =
η_g =
PRIMARY REMOVAL
WESP
η_s =
η_g =
η_f = 99 %
EMISSION
<0.1
0.2
<0.3
<0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
SCRUBBER LIQUOR
1.1
16.8
17.9
1.1
SCRUBBER LIQUOR
0.3
0
0.3
0.4
η_c = 80.4 %
3.0
20.0
23.0
3.0
CELL EFFLUENT
REDUCTION CELL
WATER TREATMENT
IMPOUND
16.0
1.9
LOSS
5.4
0.2
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F
GAS F
TOTAL F
ALUMINA
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: IIB- 2,7 VSS
OVERALL CONTROL EFFICIENCY: 93.7 %

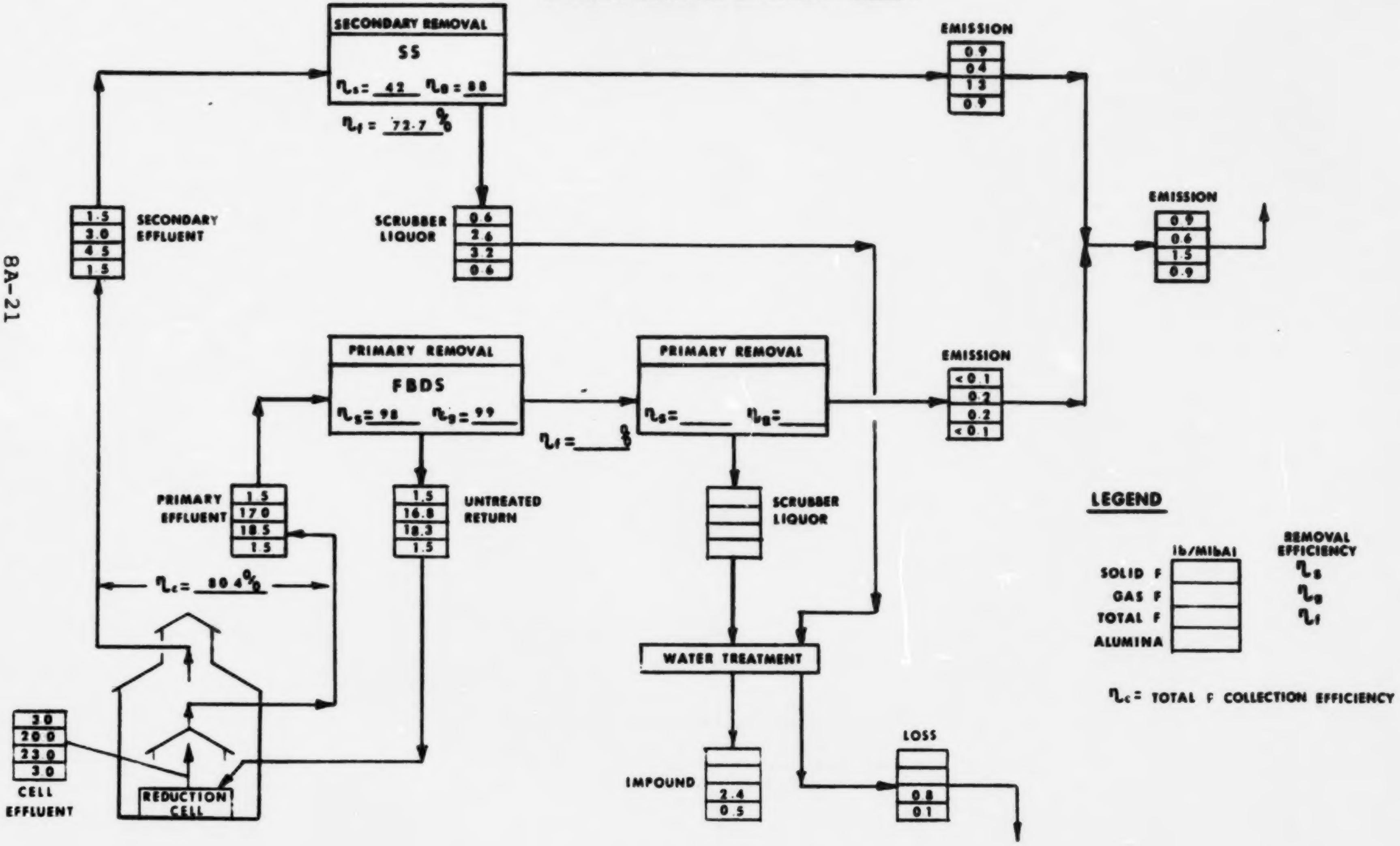

SECONDARY REMOVAL
SS
η_s = 42 η_g = 88
η_f = 72.7 %
EMISSION
0.9
0.4
1.3
0.9
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
0.6
2.6
3.2
0.6
EMISSION
0.9
0.6
1.5
0.9
PRIMARY REMOVAL
FBDS
η_s = 98 η_g = 99
PRIMARY REMOVAL
η_s = η_g =
η_f = %
EMISSION
<0.1
0.2
0.2
<0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
1.5
16.8
18.3
1.5
SCRUBBER LIQUOR
η_c = 80.4 %
WATER TREATMENT
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
IMPOUND
2.4
0.5
LOSS
0.8
0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II B-3,7 VSS
OVERALL CONTROL EFFICIENCY:_____%

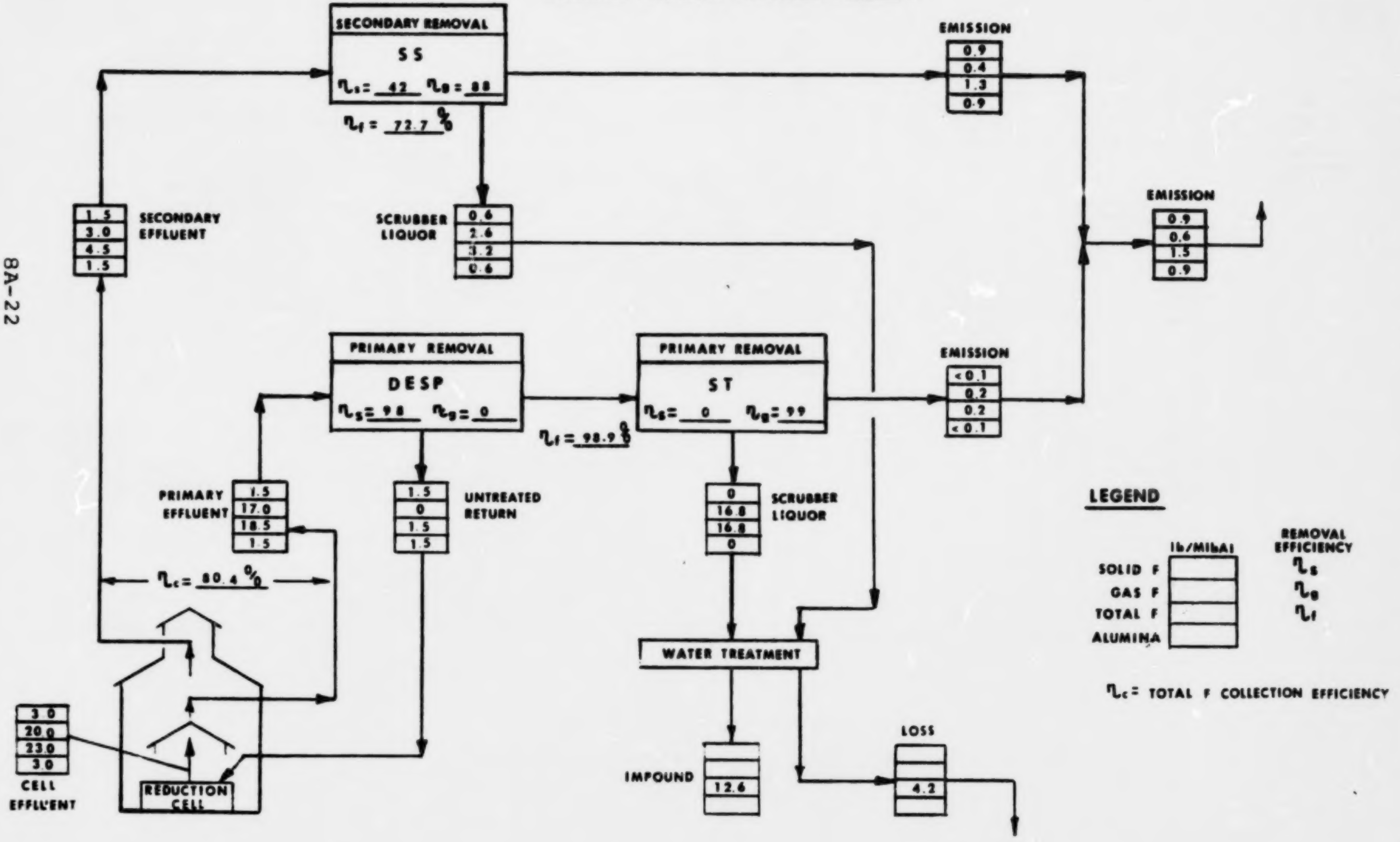

SECONDARY REMOVAL
SS
$\eta_s = 42$ $\eta_g = 88$
$\eta_f = 72.7$ %
EMISSION
0.9
0.4
1.3
0.9
EMISSION
0.9
0.6
1.5
0.9
1.5
3.0
4.5
1.5
SECONDARY EFFLUENT
SCRUBBER LIQUOR
0.6
2.6
3.2
0.6
PRIMARY REMOVAL
DESP
$\eta_s = 98$ $\eta_g = 0$
$\eta_f = 98.9$ %
PRIMARY REMOVAL
ST
$\eta_s = 0$ $\eta_g = 99$
EMISSION
<0.1
0.2
0.2
<0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
1.5
0
1.5
1.5
UNTREATED RETURN
0
16.8
16.8
0
SCRUBBER LIQUOR
$\eta_c = 80.4$ %
3.0
20.0
23.0
3.0
CELL EFFLUENT
REDUCTION CELL
WATER TREATMENT
IMPOUND
12.6
LOSS
4.2
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II B-4,7 VSS
OVERALL CONTROL EFFICIENCY: 93.6 %

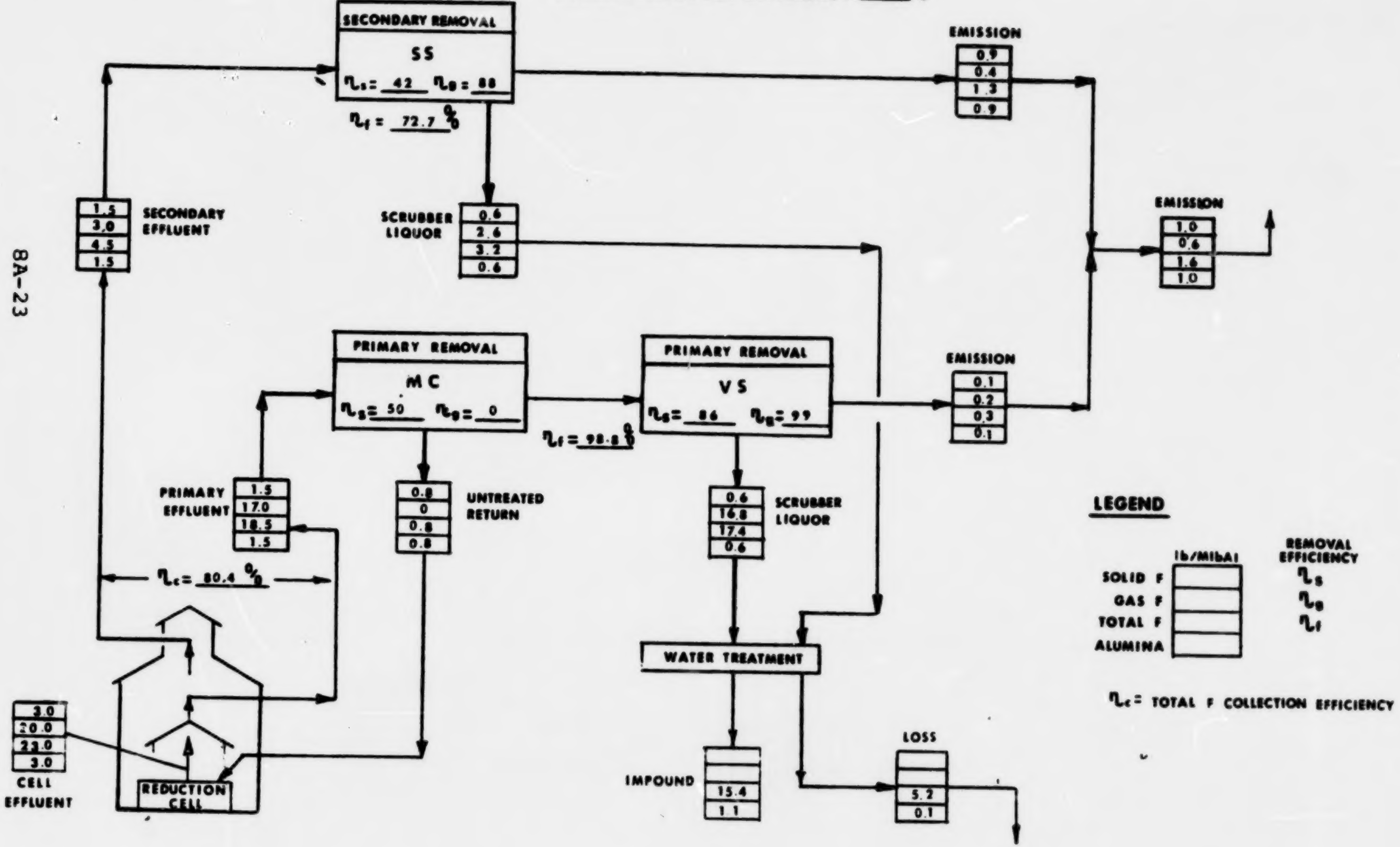

SECONDARY REMOVAL
SS
η_s = 42 η_g = 88
η_f = 72.7 %
EMISSION
0.9
0.4
1.3
0.9
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
0.6
2.6
3.2
0.6
EMISSION
1.0
0.6
1.6
1.0
PRIMARY REMOVAL
MC
η_s = 50 η_g = 0
PRIMARY REMOVAL
VS
η_s = 86 η_g = 99
η_f = 98.8 %
EMISSION
0.1
0.2
0.3
0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
0.8
0
0.8
0.8
SCRUBBER LIQUOR
0.6
16.8
17.4
0.6
η_c = 80.4 %
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
15.4
1.1
LOSS
5.2
0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II B - 5, 7 VSS
OVERALL CONTROL EFFICIENCY: 92.6 %

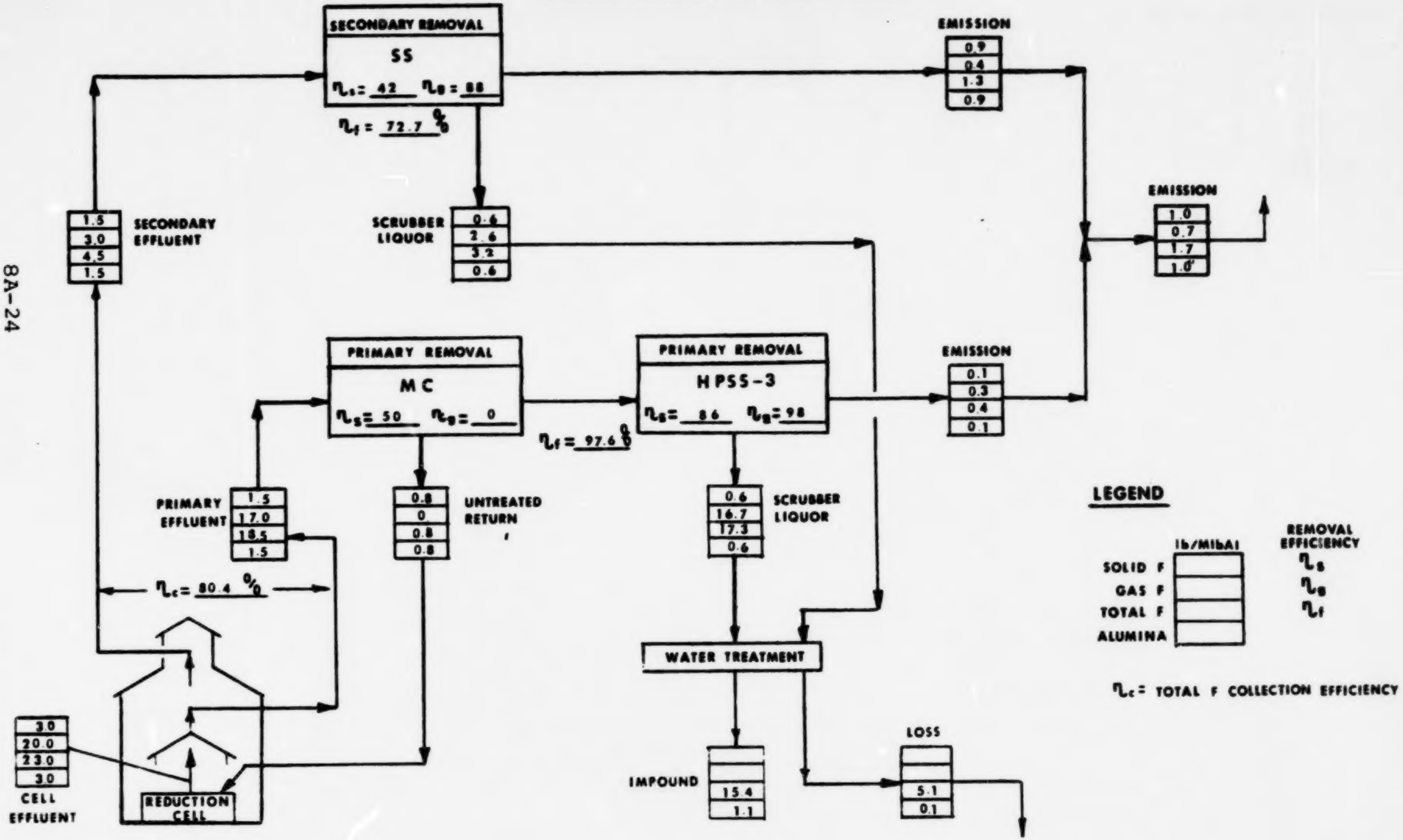

SECONDARY REMOVAL
SS
η_s = 42 η_g = 88
η_f = 72.7 %
EMISSION
0.9
0.4
1.3
0.9
EMISSION
1.0
0.7
1.7
1.0
SECONDARY EFFLUENT
1.5
3.0
4.5
1.5
SCRUBBER LIQUOR
0.6
2.6
3.2
0.6
PRIMARY REMOVAL
MC
η_s = 50 η_g = 0
η_f = 97.6 %
PRIMARY REMOVAL
HPSS-3
η_s = 86 η_g = 98
EMISSION
0.1
0.3
0.4
0.1
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
0.8
0
0.8
0.8
SCRUBBER LIQUOR
0.6
16.7
17.3
0.6
η_c = 80.4 %
WATER TREATMENT
IMPOUND
15.4
1.1
LOSS
5.1
0.1
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II B-6,7 VSS
OVERALL CONTROL EFFICIENCY: 92.2 %

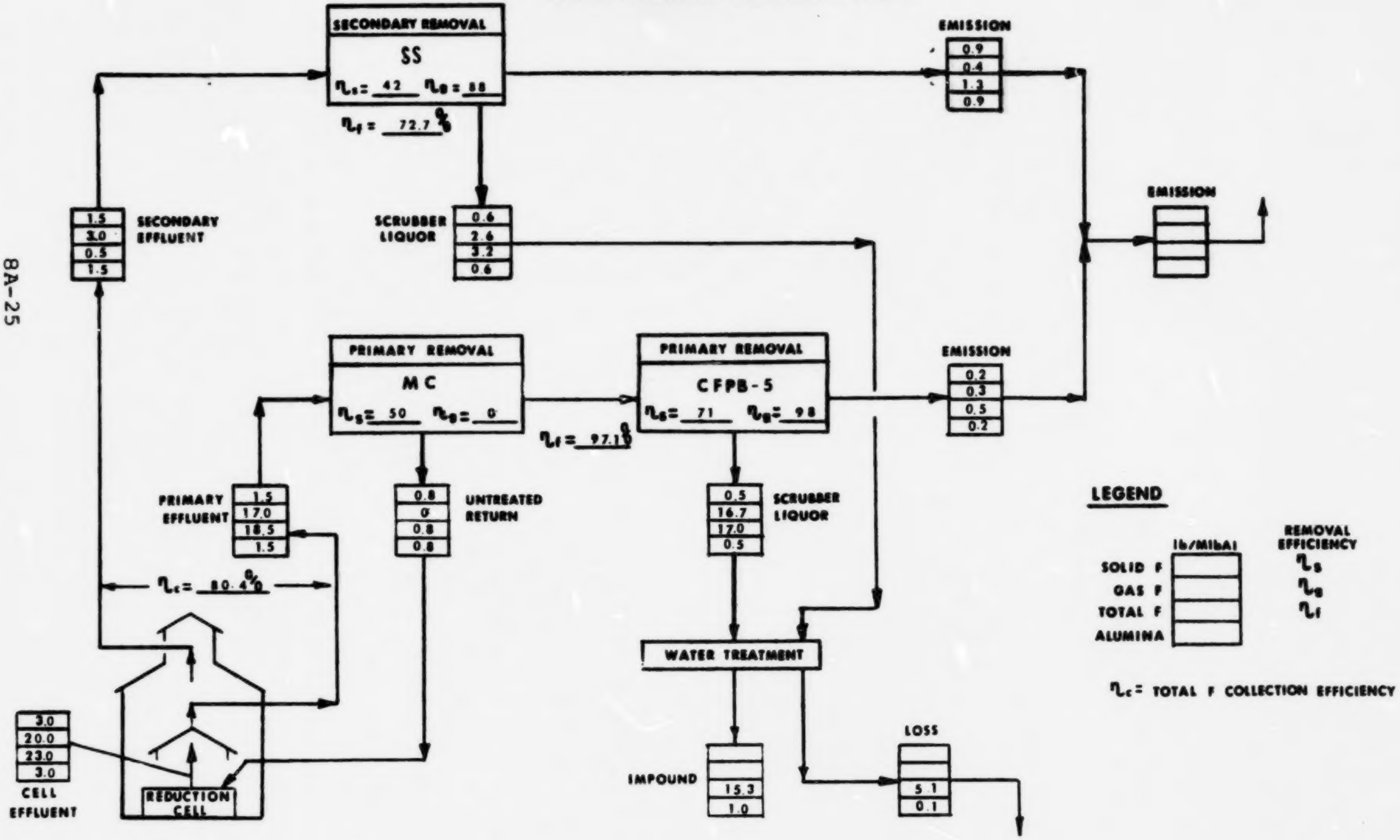

SECONDARY REMOVAL
SS
η_s = 42 η_g = 88
η_f = 72.7 %
EMISSION
0.9
0.4
1.3
0.9
EMISSION
SECONDARY EFFLUENT
1.5
3.0
0.5
1.5
SCRUBBER LIQUOR
0.6
2.6
3.2
0.6
PRIMARY REMOVAL
MC
η_s = 50 η_g = 0
PRIMARY REMOVAL
CFPB-5
η_s = 71 η_g = 98
η_f = 97.1 %
EMISSION
0.2
0.3
0.5
0.2
PRIMARY EFFLUENT
1.5
17.0
18.5
1.5
UNTREATED RETURN
0.8
0
0.8
0.8
SCRUBBER LIQUOR
0.5
16.7
17.0
0.5
η_c = 80.4 %
CELL EFFLUENT
3.0
20.0
23.0
3.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
15.3
1.0
LOSS
5.1
0.1
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III A-1 HSS
OVERALL CONTROL EFFICIENCY: 83.9 %

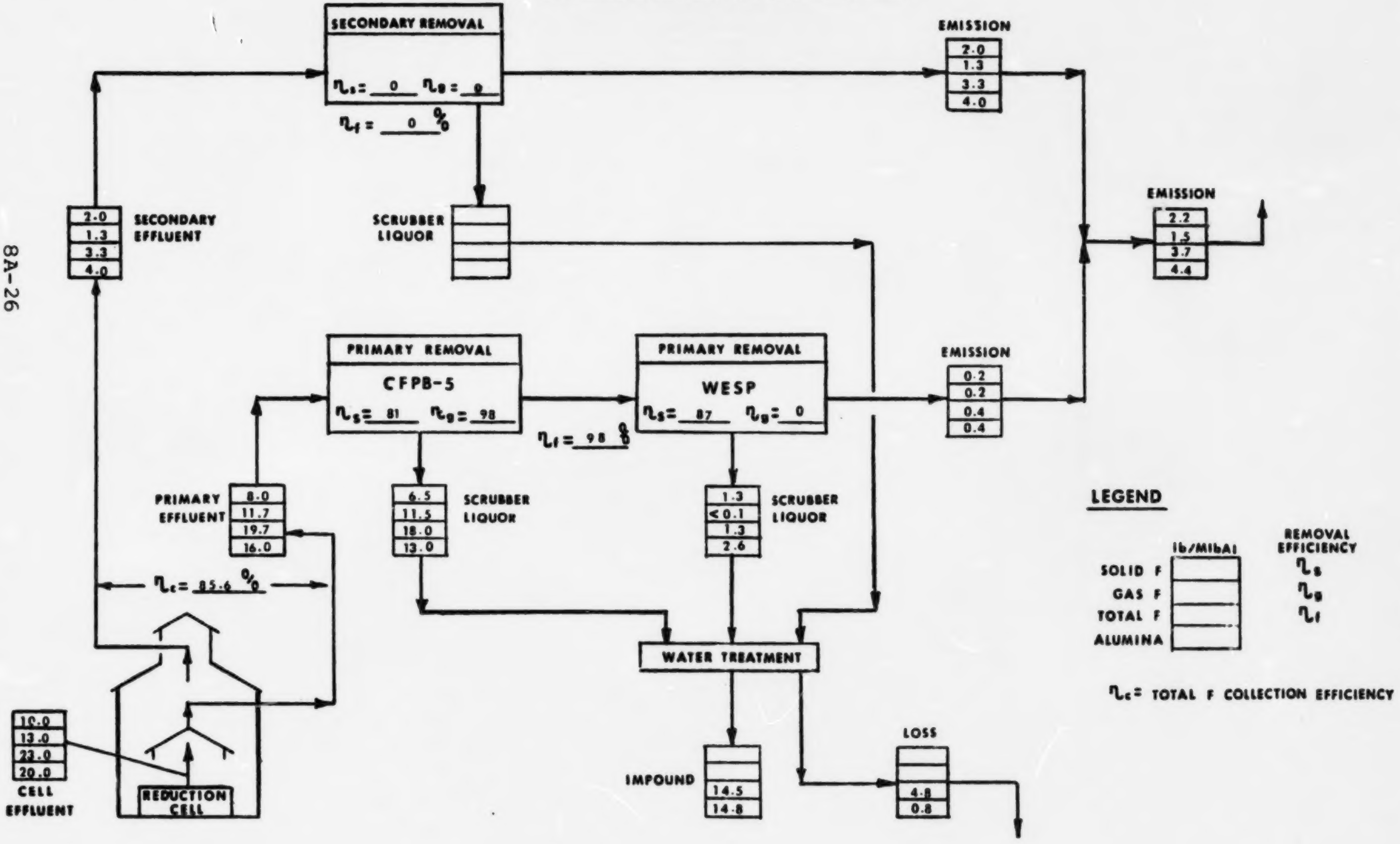

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
2.0
1.3
3.3
4.0
EMISSION
2.2
1.5
3.7
4.4
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
PRIMARY REMOVAL
CFPB-5
η_s = 81 η_g = 98
η_f = 98 %
PRIMARY REMOVAL
WESP
η_s = 87 η_g = 0
EMISSION
0.2
0.2
0.4
0.4
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
6.5
11.5
18.0
13.0
SCRUBBER LIQUOR
1.3
<0.1
1.3
2.6
η_c = 85.6 %
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
14.5
14.8
LOSS
4.8
0.8
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: II A-2 HSS
OVERALL CONTROL EFFICIENCY: 81.3 %

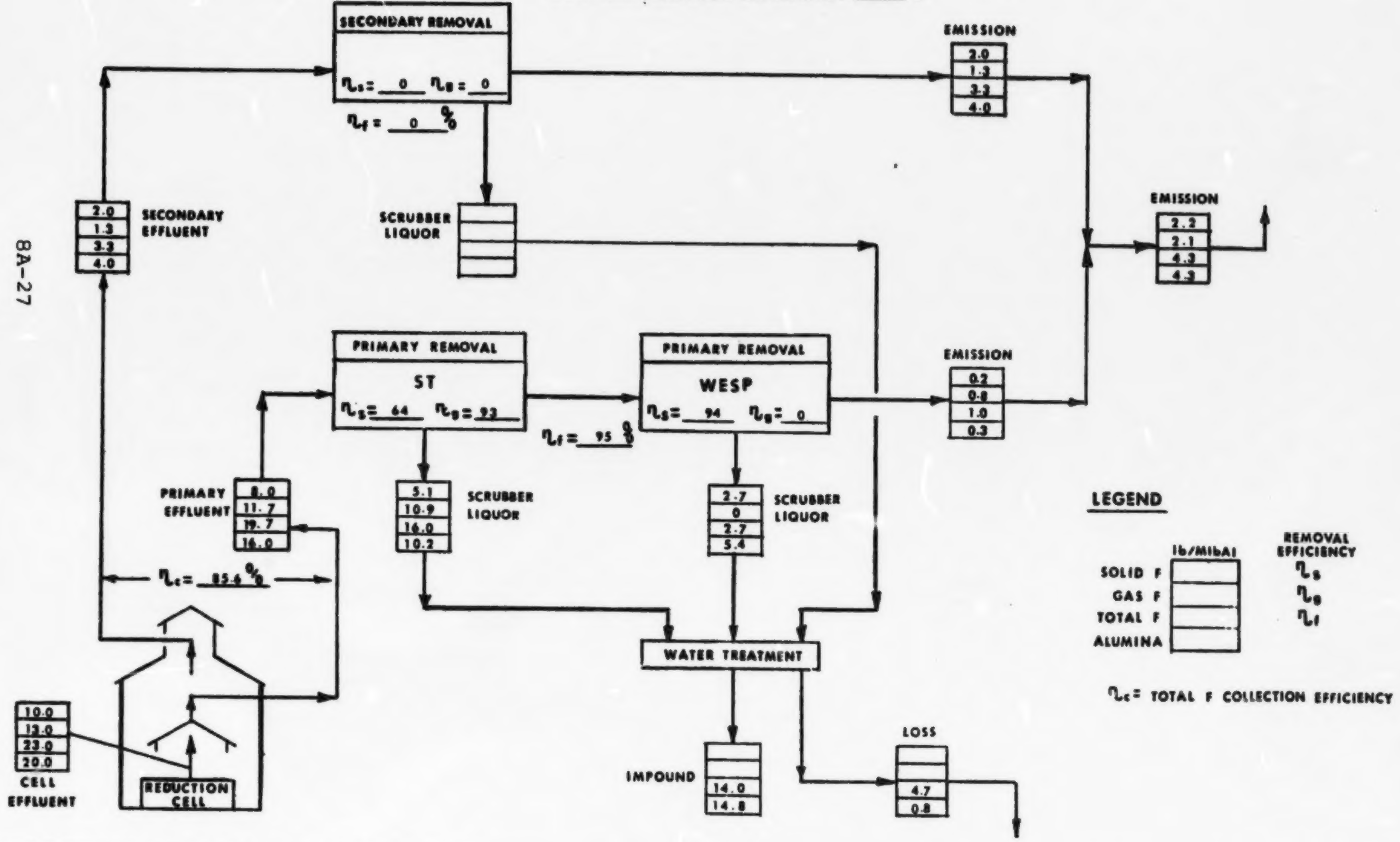

SECONDARY REMOVAL
ηs = 0 ηg = 0
ηf = 0 %
EMISSION
2.0
1.3
3.3
4.0
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
EMISSION
2.2
2.1
4.3
4.3
PRIMARY REMOVAL
ST
ηs = 64 ηg = 93
ηf = 95 %
PRIMARY REMOVAL
WESP
ηs = 94 ηg = 0
EMISSION
0.2
0.8
1.0
0.3
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
5.1
10.9
16.0
10.2
SCRUBBER LIQUOR
2.7
0
2.7
5.4
ηc = 85.4 %
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
ηs
ηg
ηf
ηc = TOTAL F COLLECTION EFFICIENCY
WATER TREATMENT
10.0
13.0
23.0
20.0
CELL EFFLUENT
REDUCTION CELL
IMPOUND
14.0
14.8
LOSS
4.7
0.8

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III A-3 HSS
OVERALL CONTROL EFFICIENCY: 78 %

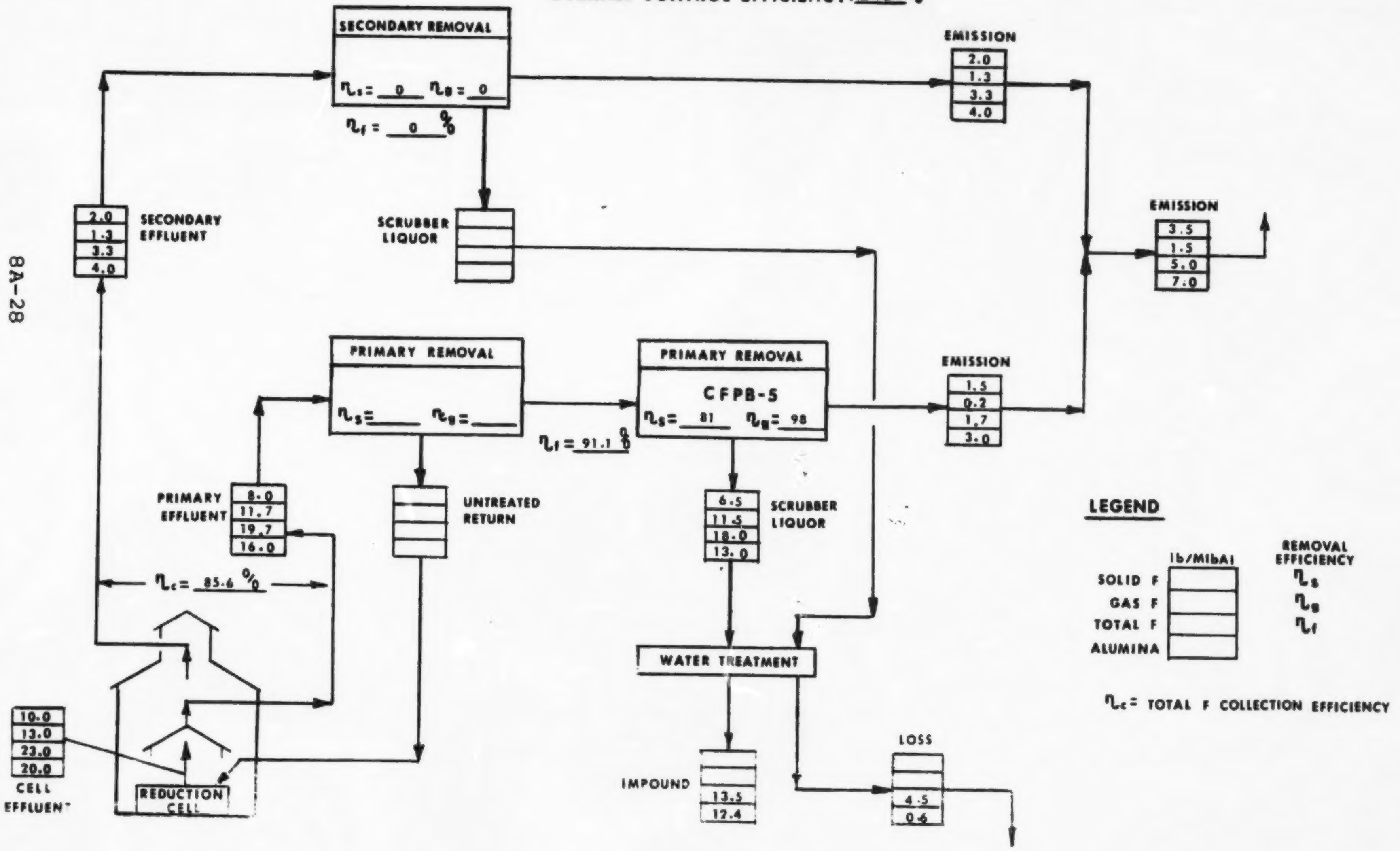

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
2.0
1.3
3.3
4.0
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
EMISSION
3.5
1.5
5.0
7.0
PRIMARY REMOVAL
η_s = η_g =
PRIMARY REMOVAL
CFPB-5
η_s = 81 η_g = 98
η_f = 91.1 %
EMISSION
1.5
0.2
1.7
3.0
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
UNTREATED RETURN
SCRUBBER LIQUOR
6.5
11.5
18.0
13.0
η_c = 85.6 %
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY
WATER TREATMENT
10.0
13.0
23.0
20.0
CELL EFFLUENT
REDUCTION CELL
IMPOUND
13.5
12.4
LOSS
4.5
0.6

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III A-4 HSS
OVERALL CONTROL EFFICIENCY: 70.2 %

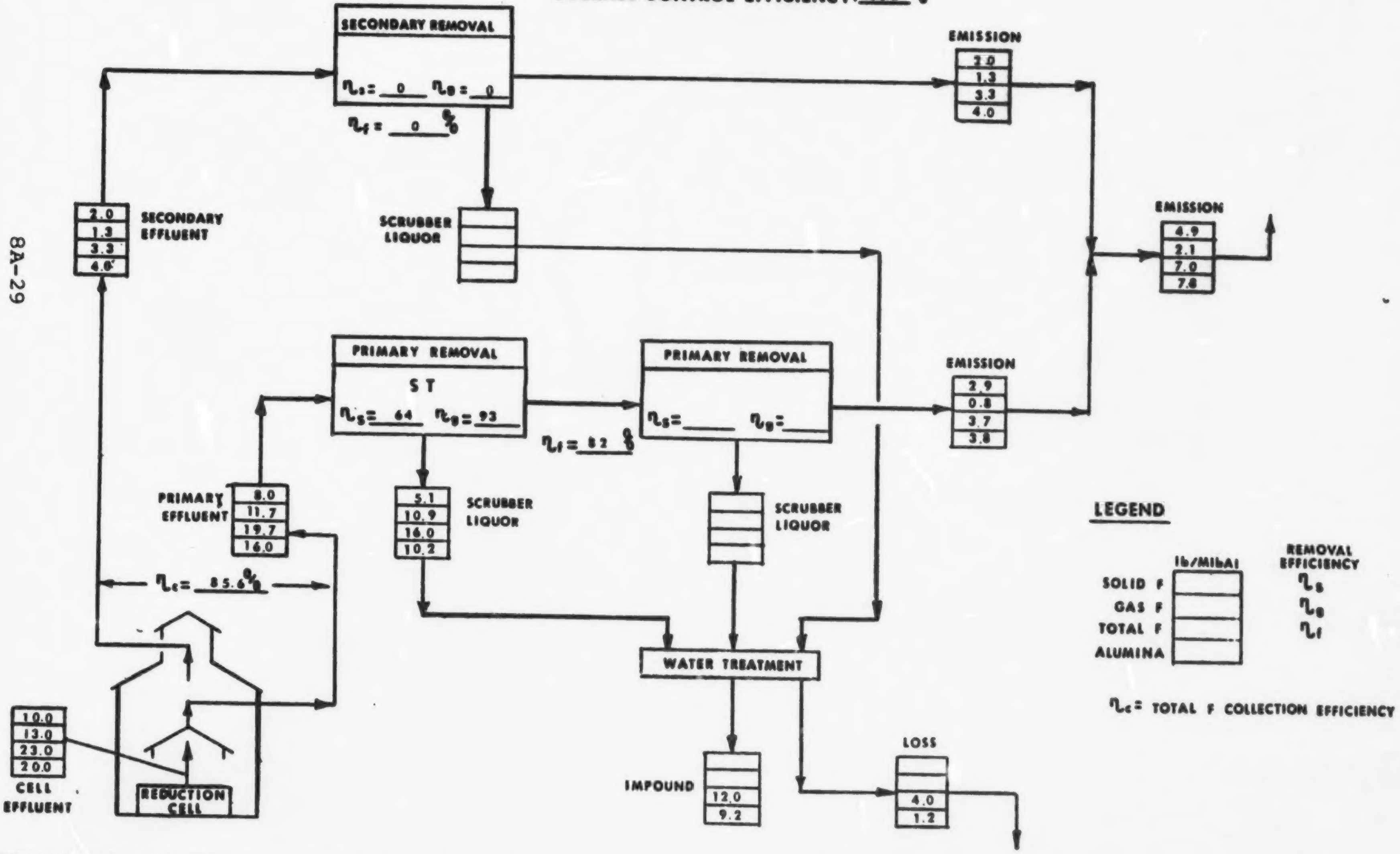

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
EMISSION
4.9
2.1
7.0
7.8
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
PRIMARY REMOVAL
S T
η_s = 64 η_g = 93
η_f = 82 %
PRIMARY REMOVAL
η_s = η_g =
EMISSION
2.9
0.8
3.7
3.8
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
5.1
10.9
16.0
10.2
SCRUBBER LIQUOR
η_c = 85.6 %
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
WATER TREATMENT
IMPOUND
12.0
9.2
LOSS
4.0
1.2
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III A-5 HSS
OVERALL CONTROL EFFICIENCY: 76.9 %

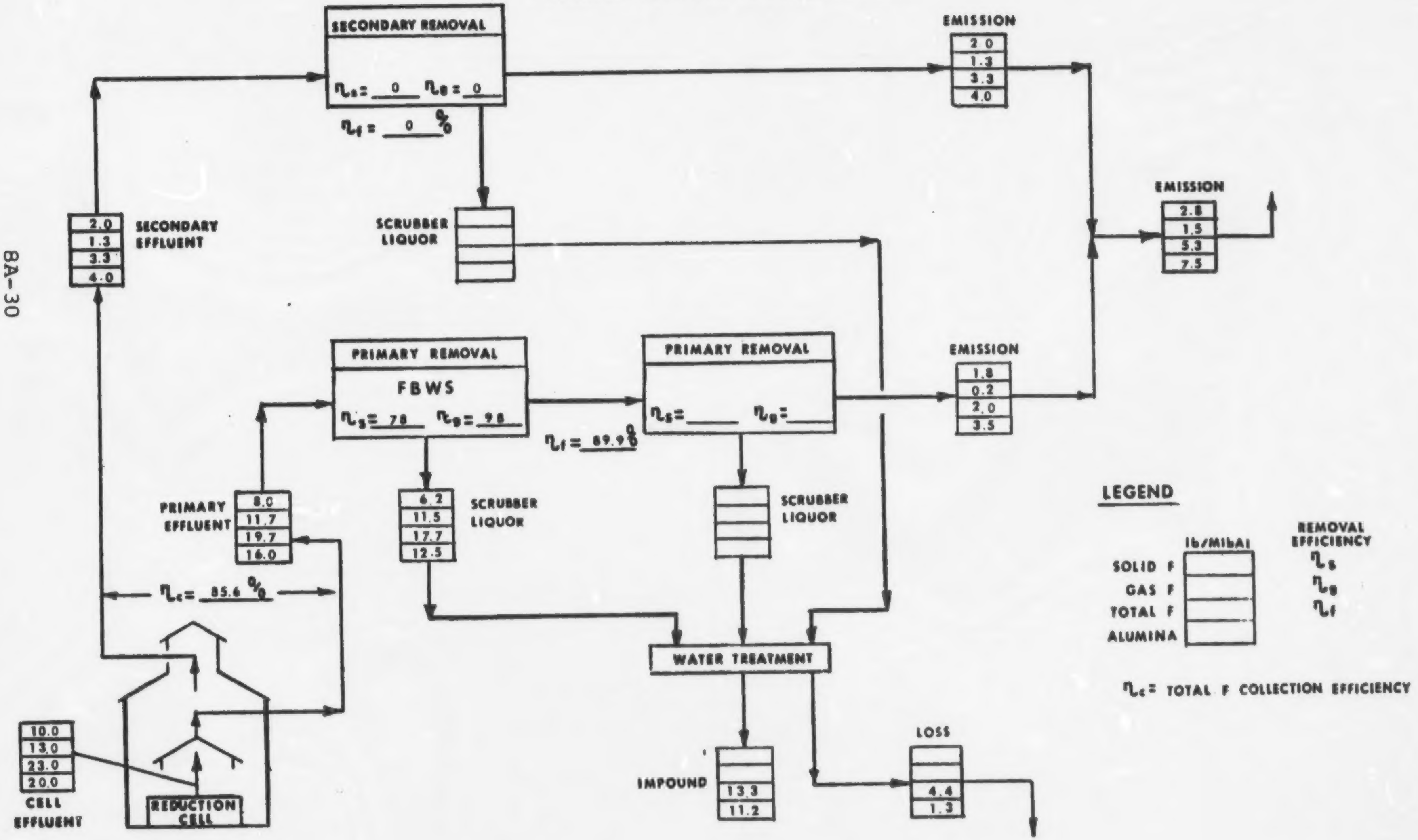

SECONDARY REMOVAL
η_s = 0 η_g = 0
η_f = 0 %
EMISSION
2.0
1.3
3.3
4.0
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
EMISSION
2.8
1.5
5.3
7.5
PRIMARY REMOVAL
FBWS
η_s = 78 η_g = 98
η_f = 89.9 %
PRIMARY REMOVAL
η_s = η_g =
EMISSION
1.8
0.2
2.0
3.5
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
6.2
11.5
17.7
12.5
SCRUBBER LIQUOR
η_c = 85.6 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
13.3
11.2
LOSS
4.4
1.3
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III B-1, 6 HSS
OVERALL CONTROL EFFICIENCY: 92.1 %

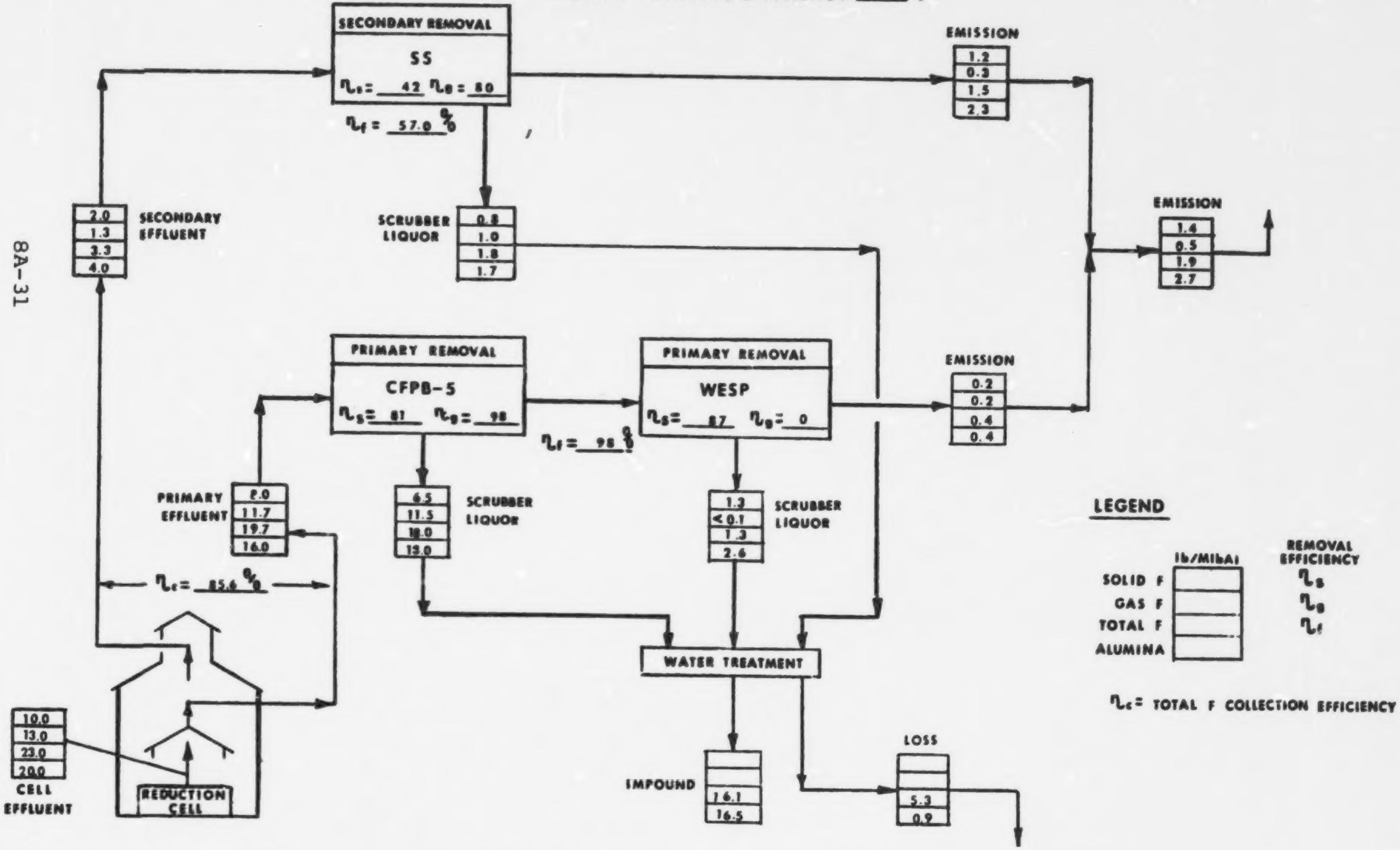

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 57.0 %
EMISSION
1.2
0.3
1.5
2.3
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
0.8
1.0
1.8
1.7
EMISSION
1.4
0.5
1.9
2.7
PRIMARY REMOVAL
CFPB-5
η_s = 81 η_g = 98
PRIMARY REMOVAL
WESP
η_s = 87 η_g = 0
η_f = 98 %
EMISSION
0.2
0.2
0.4
0.4
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
6.5
11.5
18.0
13.0
SCRUBBER LIQUOR
1.3
<0.1
1.3
2.6
η_c = 85.6 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
16.1
16.5
LOSS
5.3
0.9
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III B-2,6 HSS
OVERALL CONTROL EFFICIENCY: 81.3 %

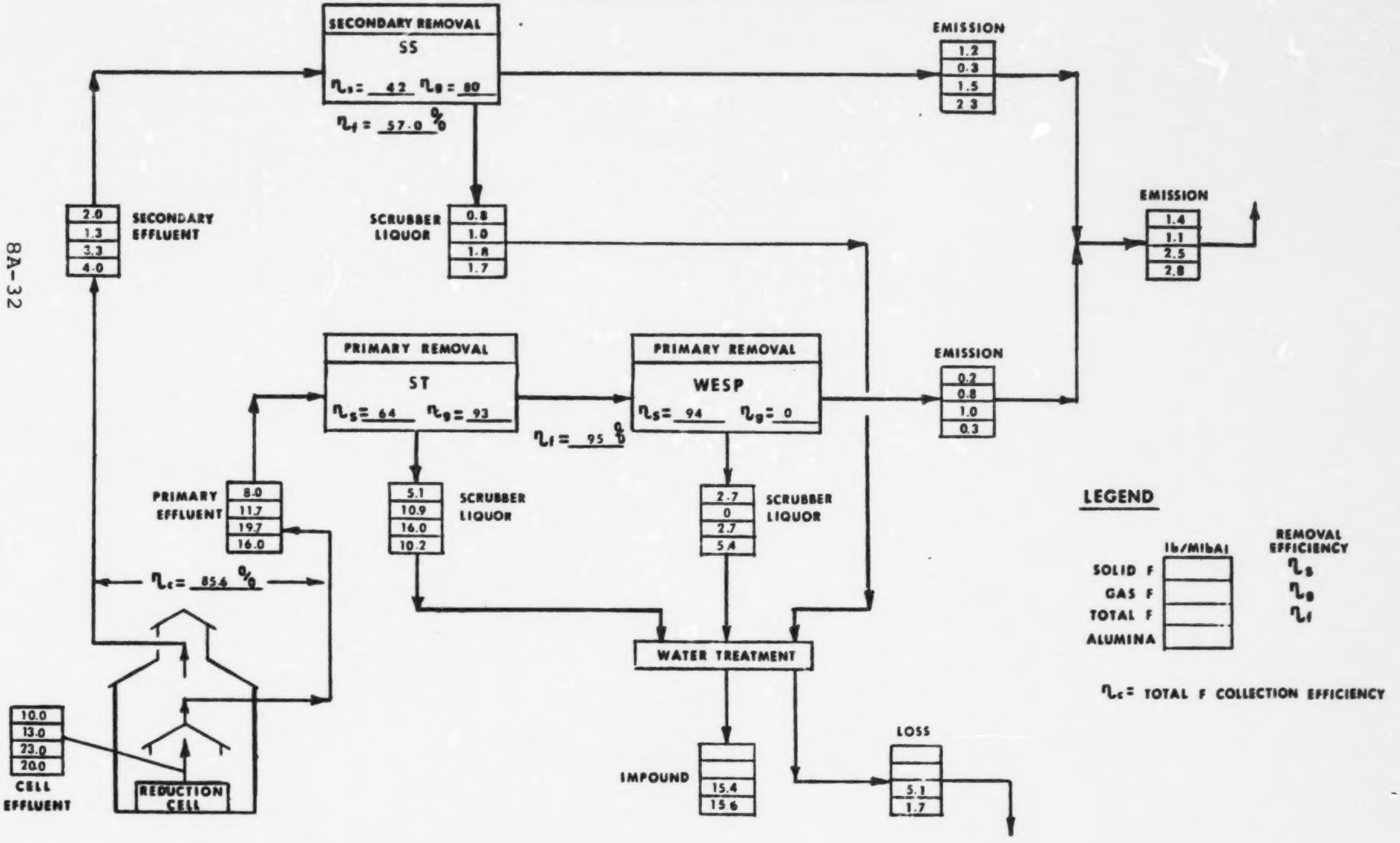

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 57.0 %
EMISSION
1.2
0.3
1.5
2.3
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
0.8
1.0
1.8
1.7
EMISSION
1.4
1.1
2.5
2.8
PRIMARY REMOVAL
ST
η_s = 64 η_g = 93
PRIMARY REMOVAL
WESP
η_s = 94 η_g = 0
η_f = 95 %
EMISSION
0.2
0.8
1.0
0.3
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
5.1
10.9
16.0
10.2
SCRUBBER LIQUOR
2.7
0
2.7
5.4
η_c = 85.6 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
15.4
15.6
LOSS
5.1
1.7
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F η_s
GAS F η_g
TOTAL F η_f
ALUMINA
η_c = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III B–3.6 HSS
OVERALL CONTROL EFFICIENCY: 86.2 %

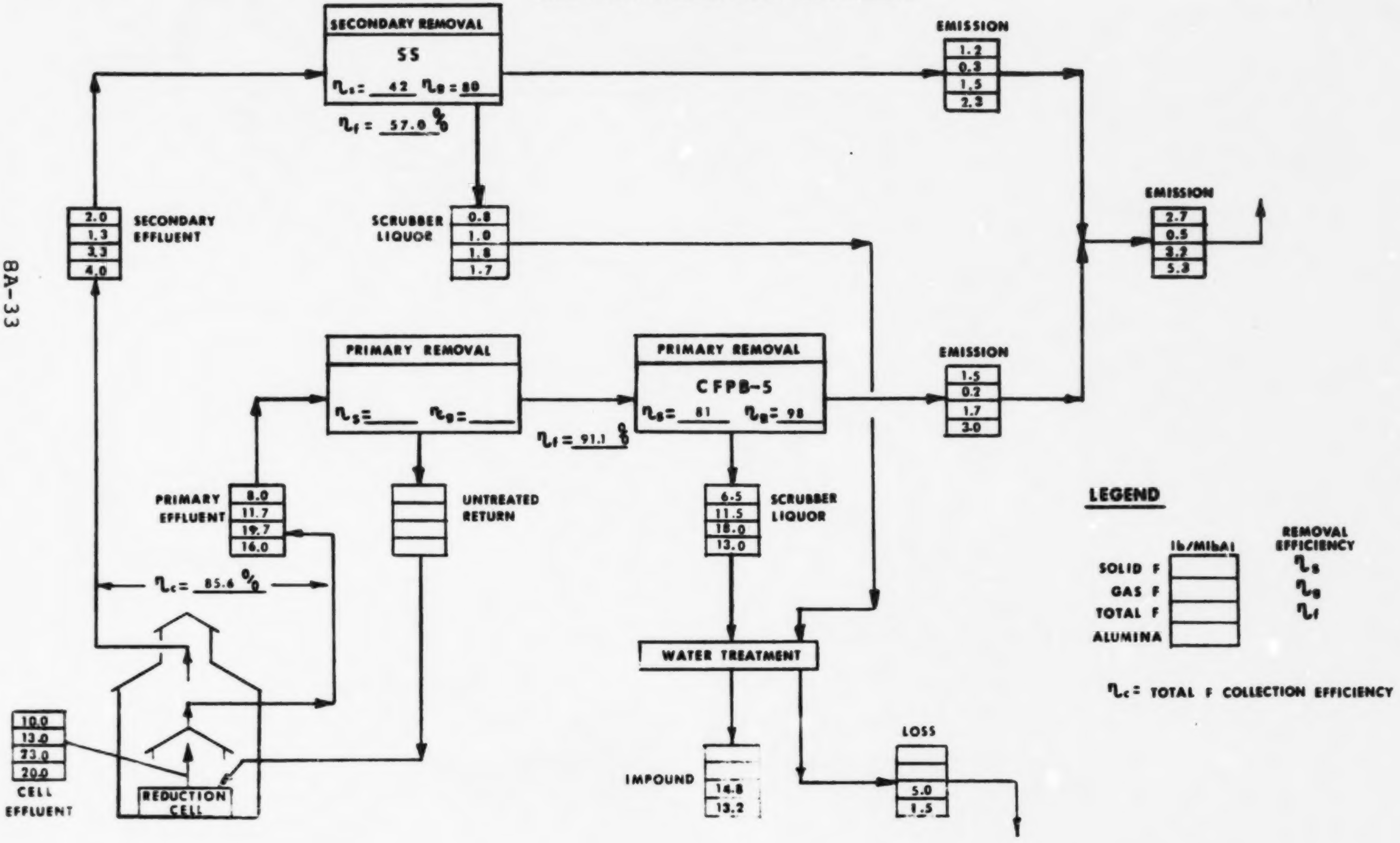

SECONDARY REMOVAL
SS
η_s = 42 η_g = 80
η_f = 57.0 %
EMISSION
1.2
0.3
1.5
2.3
EMISSION
2.7
0.5
3.2
5.3
2.0
1.3
3.3
4.0
SECONDARY EFFLUENT
SCRUBBER LIQUOR
0.8
1.0
1.8
1.7
PRIMARY REMOVAL
η_s= η_g=
PRIMARY REMOVAL
CFPB-5
η_s= 81 η_g= 98
η_f = 91.1 %
EMISSION
1.5
0.2
1.7
3.0
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
UNTREATED RETURN
6.5
11.5
18.0
13.0
SCRUBBER LIQUOR
η_c = 85.6 %
WATER TREATMENT
10.0
13.0
23.0
20.0
CELL EFFLUENT
REDUCTION CELL
IMPOUND
14.8
13.2
LOSS
5.0
1.5
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F
GAS F
TOTAL F
ALUMINA
η_s
η_g
η_f
η_c= TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III B-4,6
OVERALL CONTROL EFFICIENCY: 78.4 %

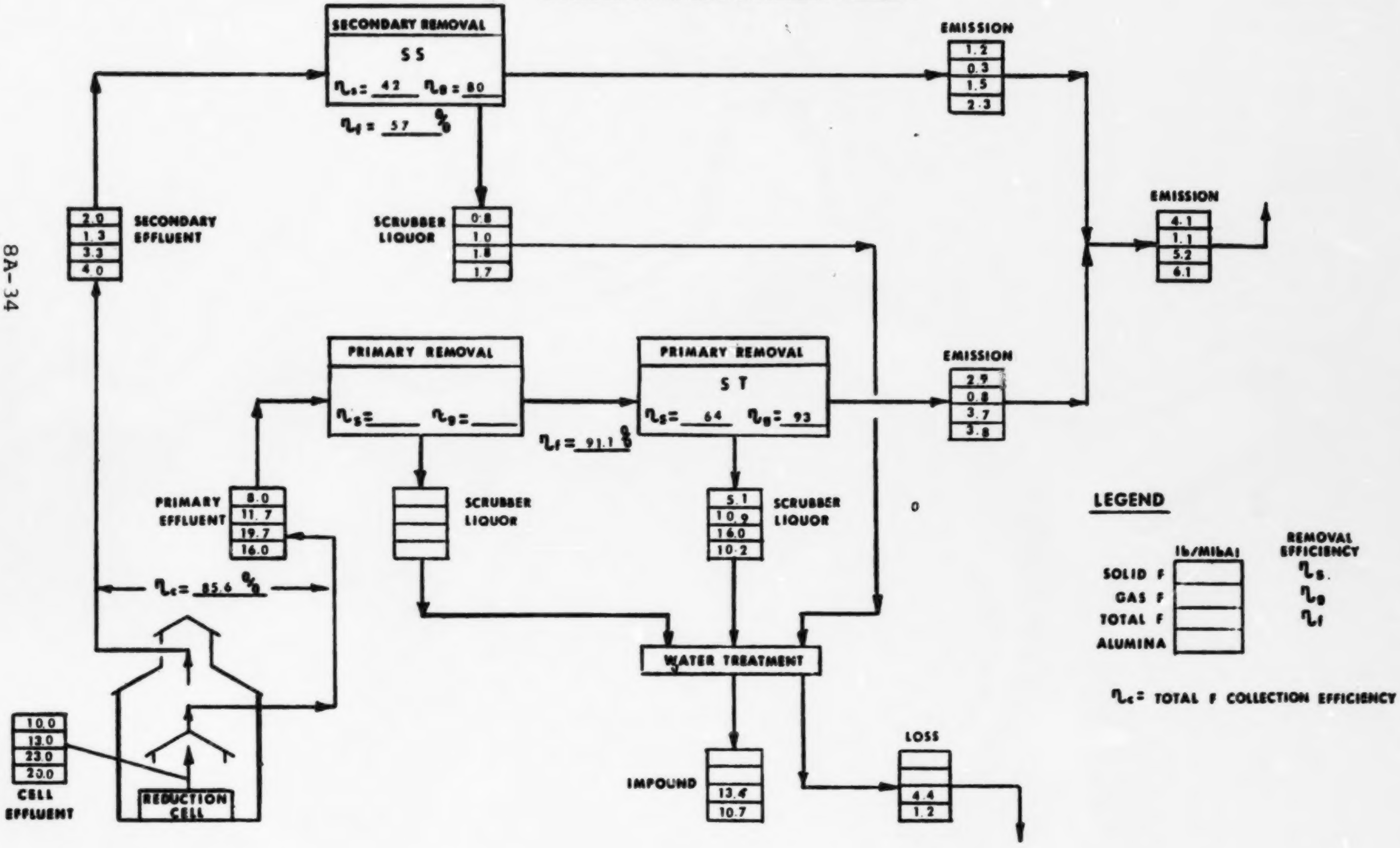
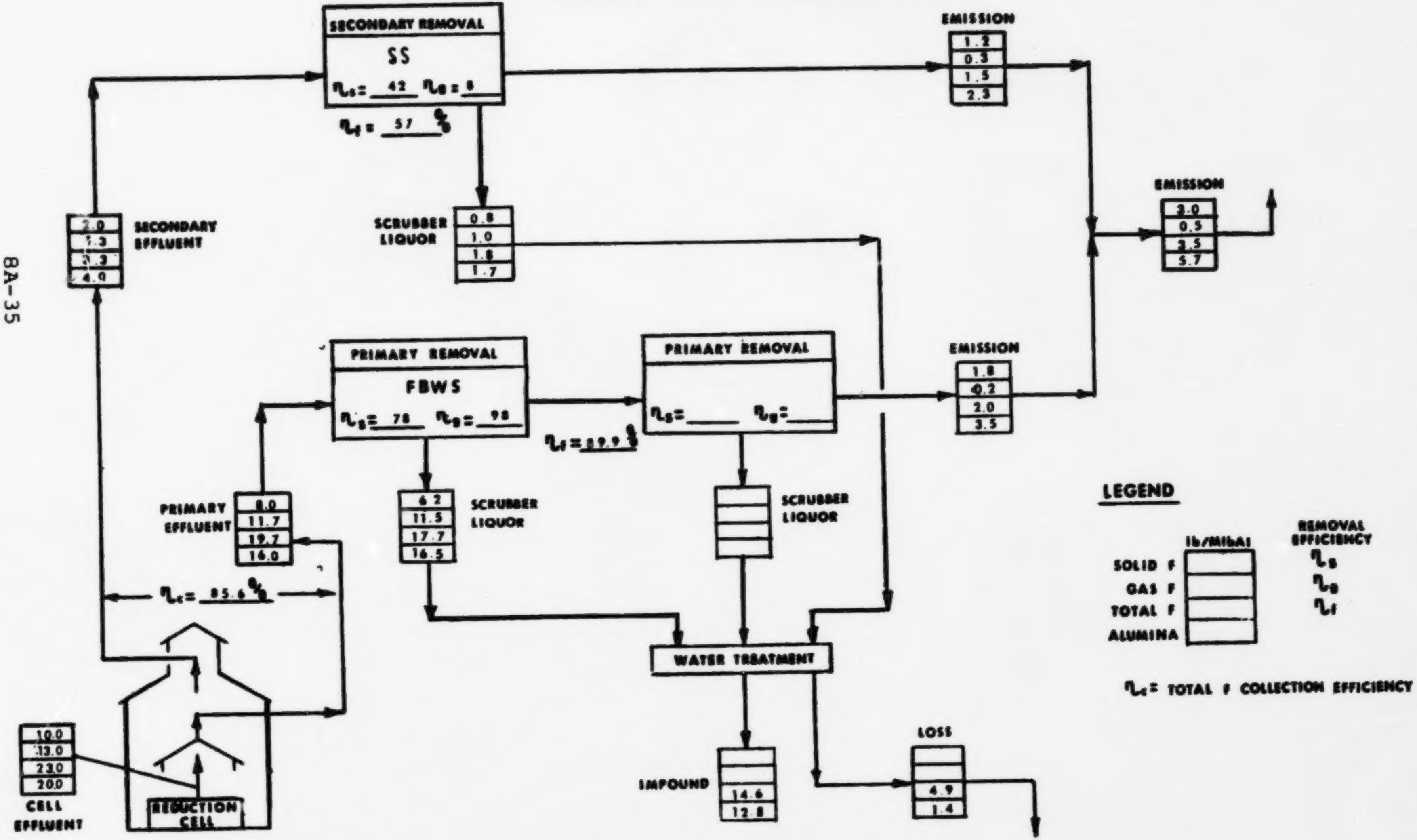

SECONDARY REMOVAL
SS
ηs = 42
ηg = 80
ηf = 57 %
EMISSION
1.2
0.3
1.5
2.3
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
0.8
1.0
1.8
1.7
EMISSION
4.1
1.1
5.2
6.1
PRIMARY REMOVAL
ηs =
ηg =
PRIMARY REMOVAL
ST
ηs = 64
ηg = 93
ηf = 91.1 %
EMISSION
2.9
0.8
3.7
3.8
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
SCRUBBER LIQUOR
5.1
10.9
16.0
10.2
ηc = 85.6 %
WATER TREATMENT
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
IMPOUND
13.4
10.7
LOSS
4.4
1.2
LEGEND
lb/MlbAl
REMOVAL EFFICIENCY
SOLID F
GAS F
TOTAL F
ALUMINA
ηs
ηg
ηf
ηc = TOTAL F COLLECTION EFFICIENCY

FIGURE 8.1
SCHEMATIC FLOW DIAGRAM
ALUMINUM SMELTER AIR POLLUTION CONTROL
SYSTEM MODEL: III B-5, 6 HSS
OVERALL CONTROL EFFICIENCY: 85.1 %


SECONDARY REMOVAL
SS
η_s = 42 η_g = 8
η_f = 57 %
EMISSION
1.2
0.3
1.5
2.3
EMISSION
3.0
0.5
3.5
5.7
SECONDARY EFFLUENT
2.0
1.3
3.3
4.0
SCRUBBER LIQUOR
0.8
1.0
1.8
1.7
PRIMARY REMOVAL
FBWS
η_s = 78 η_g = 98
η_f = 89.9 %
PRIMARY REMOVAL
η_s = η_g =
EMISSION
1.8
0.2
2.0
3.5
PRIMARY EFFLUENT
8.0
11.7
19.7
16.0
SCRUBBER LIQUOR
6.2
11.5
17.7
16.5
SCRUBBER LIQUOR
η_c = 85.6 %
WATER TREATMENT
IMPOUND
14.6
12.8
LOSS
4.9
1.4
CELL EFFLUENT
10.0
13.0
23.0
20.0
REDUCTION CELL
LEGEND
lb/MlbAl
SOLID F
GAS F
TOTAL F
ALUMINA
REMOVAL EFFICIENCY
η_s
η_g
η_f
η_c = TOTAL F COLLECTION EFFICIENCY

Appendix 8B

Removal Equipment Purchase Costs

Capital costs for pollutant removal equipment which were developed in Section 8.2 of this report were derived from purchase costs reported by equipment manufacturers. In general, the cost of equipment per unit of flow rate goes down as its size increases; one 100,000 cfm unit is usually less costly than two 50,000 cfm units. In order to show this relationship between equipment capacity and unit cost, manufacturers were asked to provide purchase price data at several flow rates. These data are plotted in the following curves as total purchase price versus outlet flow rate from the equipment. They represent estimated FOB prices for typical equipment and are believed to reflect average 1970 prices.

The costs of removal equipment for the capacities required by the control models were taken from these curves.

FIGURE 8-B-1
REMOVAL EQUIPMENT
PURCHASE COST
(1970)

MUTIPLE CYCLONE

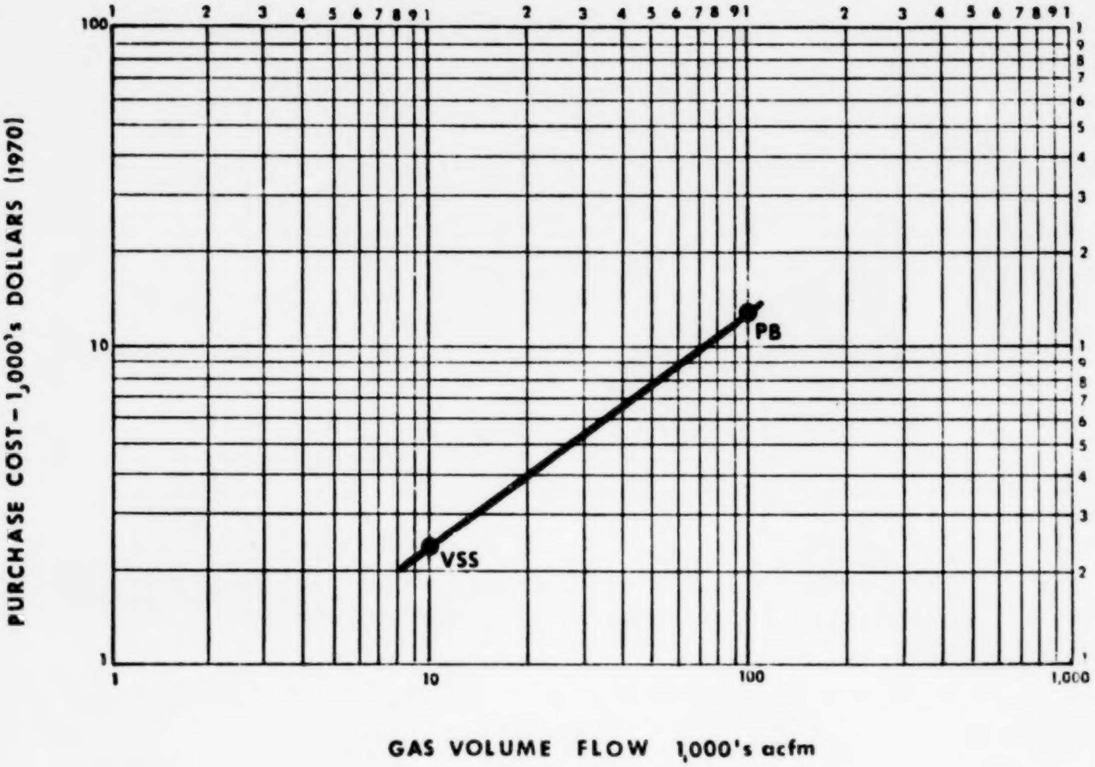


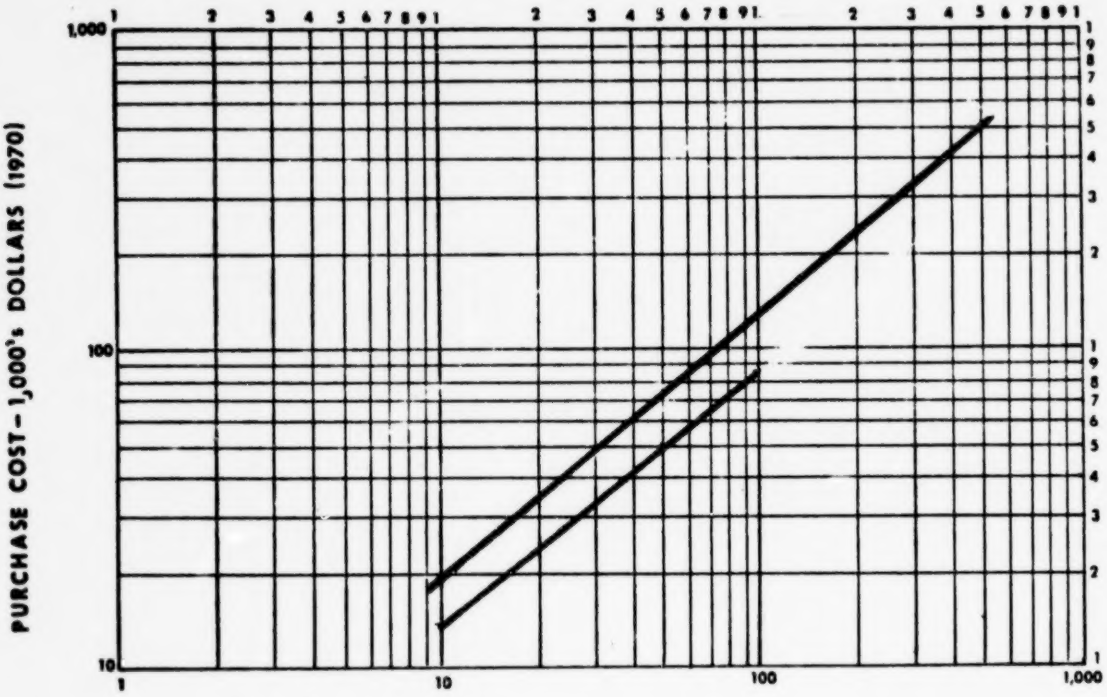
FIGURE 8B-2

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

BAGHOUSE FILTER



GAS VOLUME FLOW 1,000's acfm

SOURCE - MANUFACTURER

═ INDICATE RANGE OF DATA

FIGURE 8-B-3

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

DRY ELECTROSTATIC PRECIPITATORS

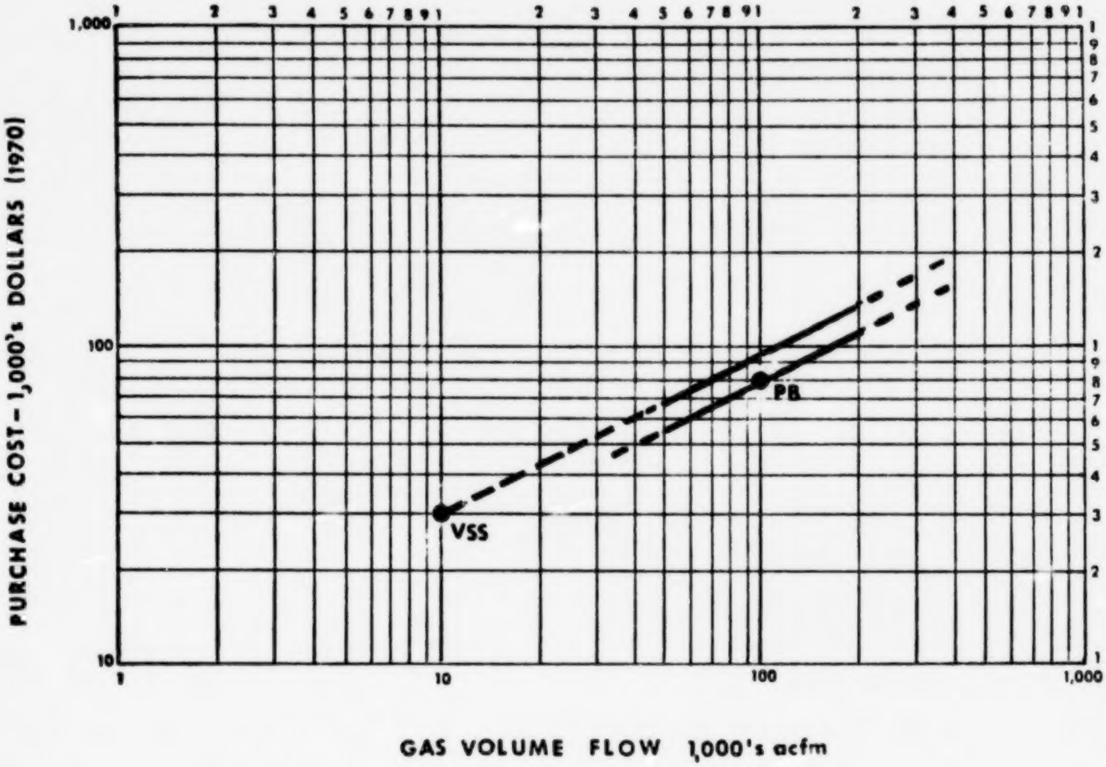
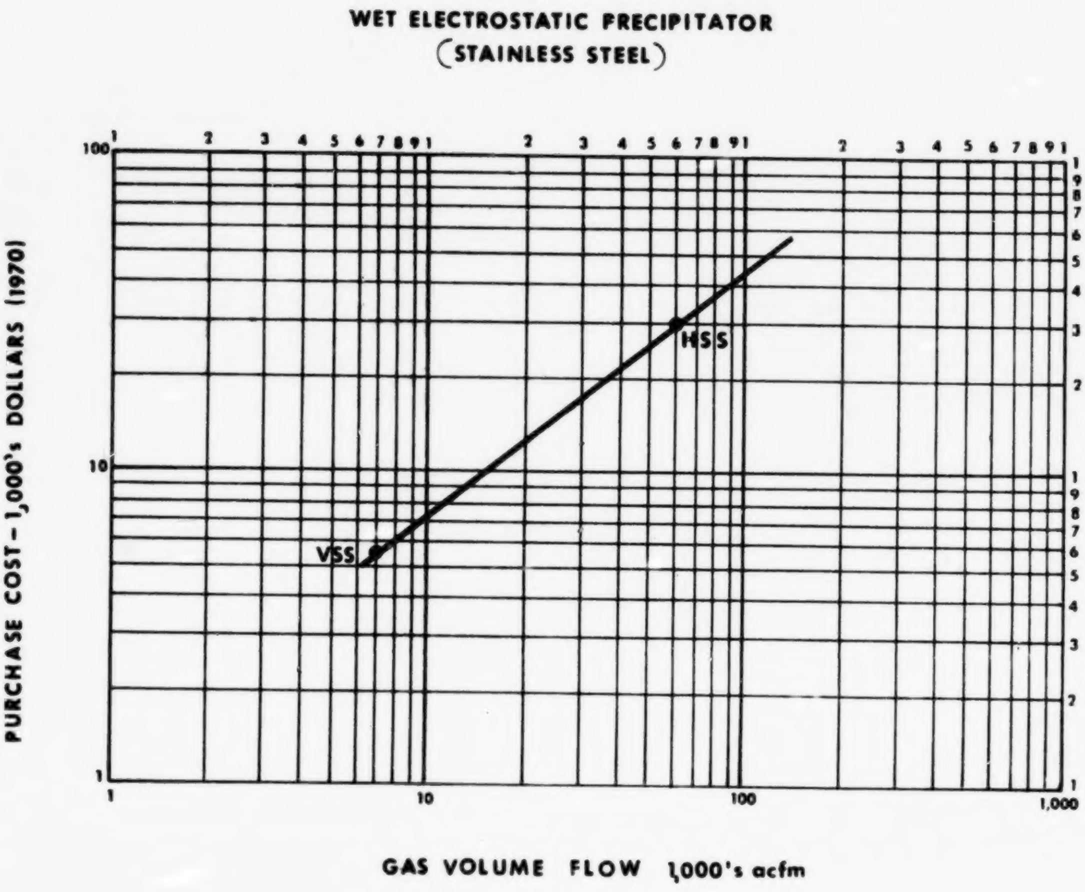


FIGURE 8B-4

REMOVAL EQUIPMENT

PURCHASE COST

(1970)



SOURCE – MANUFACTURE

FIGURE 8-B-5

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

SPRAY TOWERS

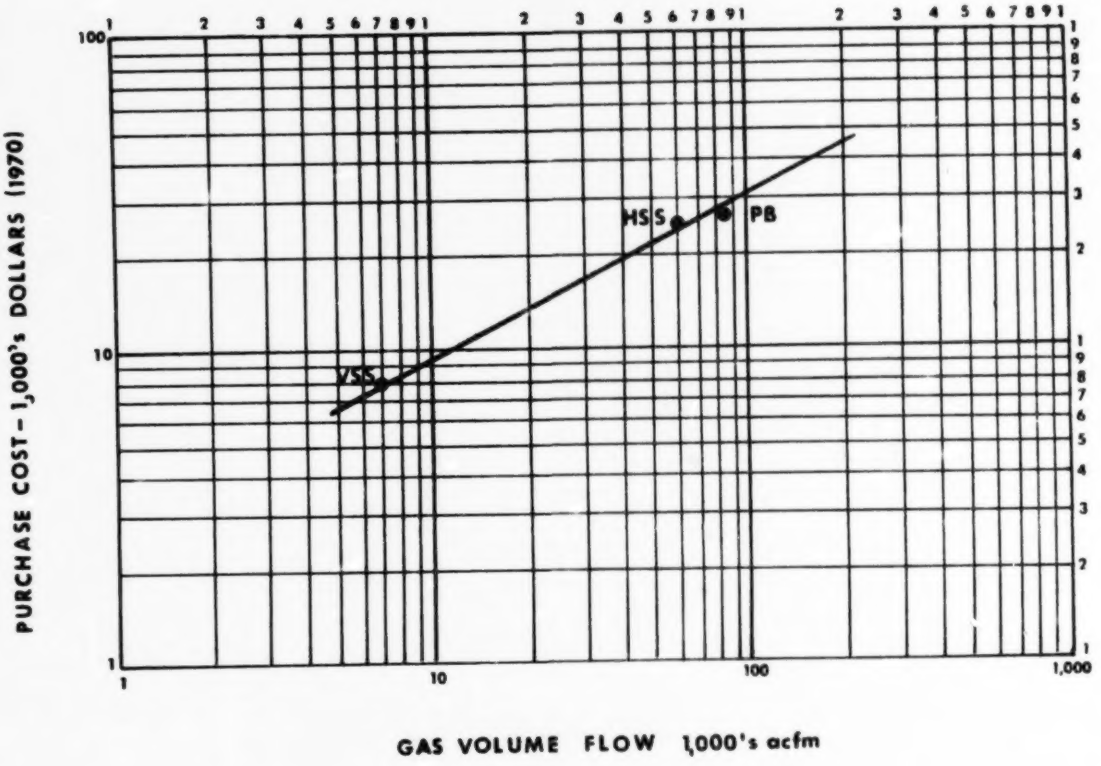


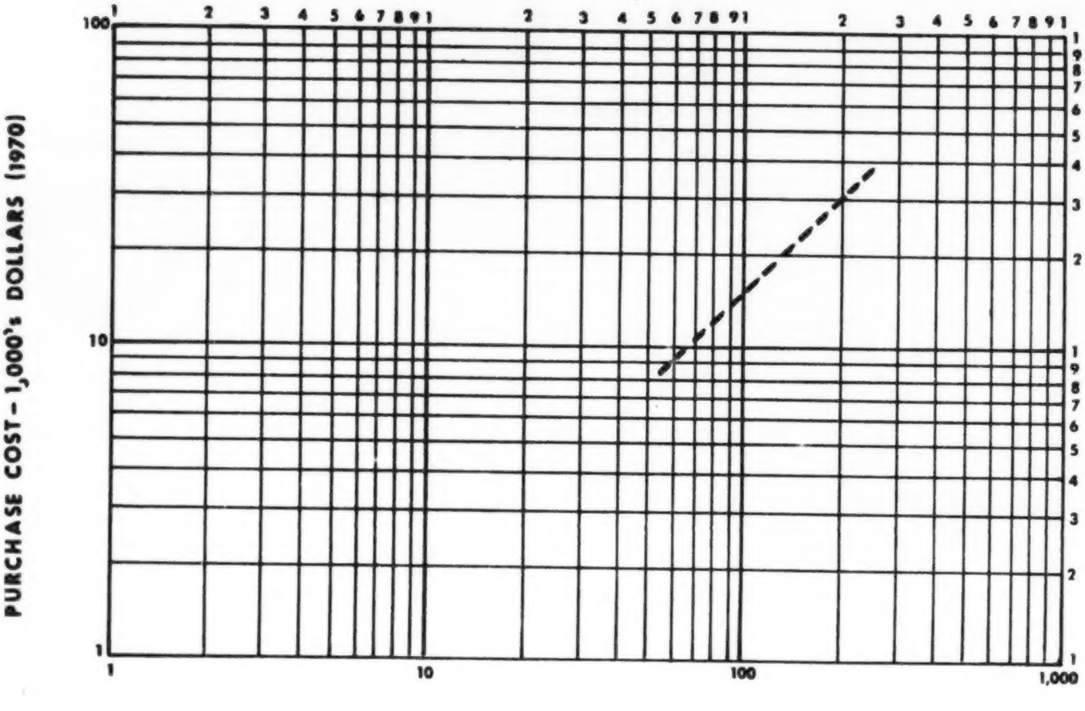
FIGURE 8B–6

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

SPRAY SCREEN



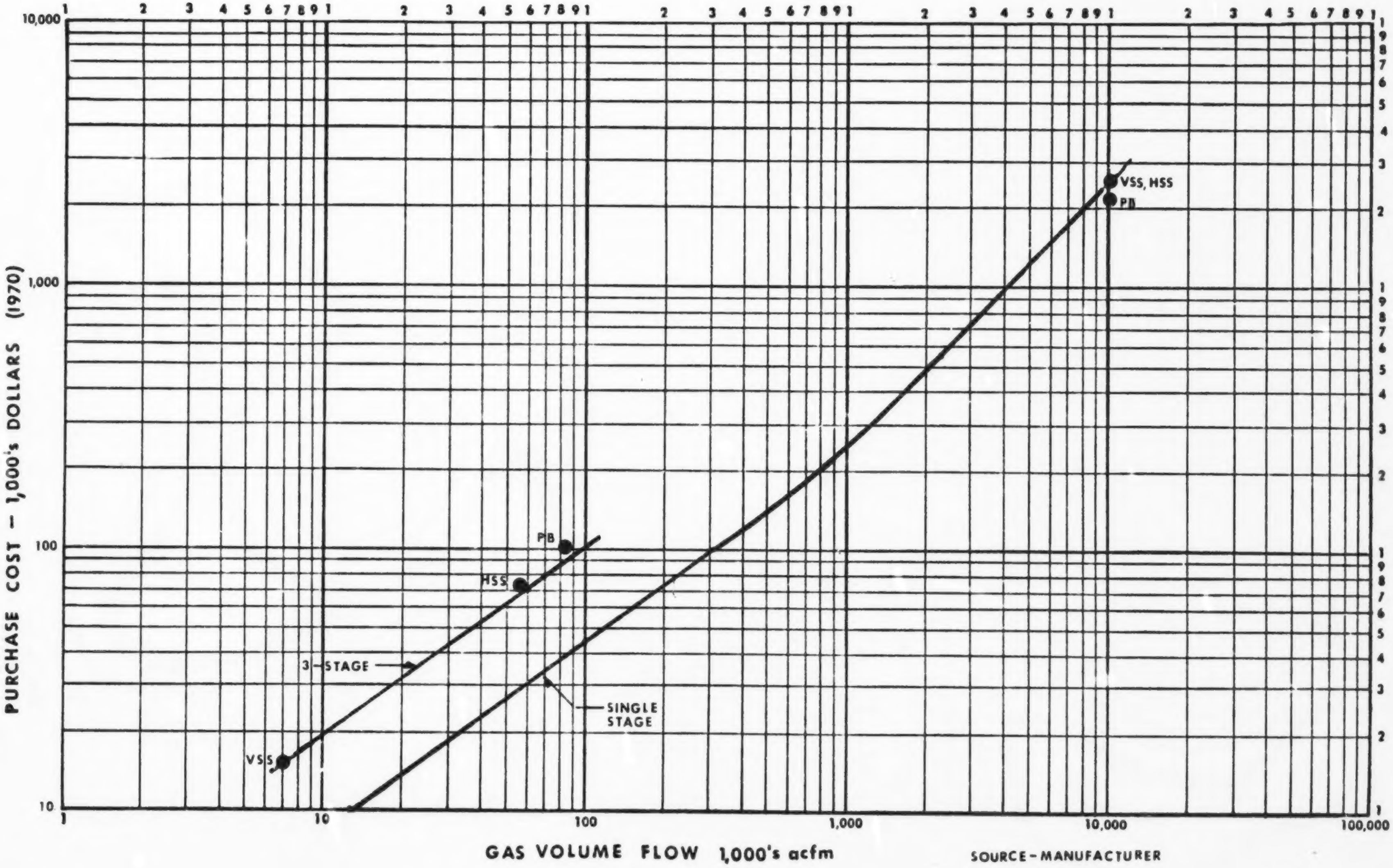
GAS VOLUME FLOW 1,000's acfm

SOURCE- INDUSTRY QUESTIONNAIRE

FIGURE 8-B-7

PURCHASE COST REMOVAL EQUIPMENT (1970)

HIGH PRESSURE SCREEN



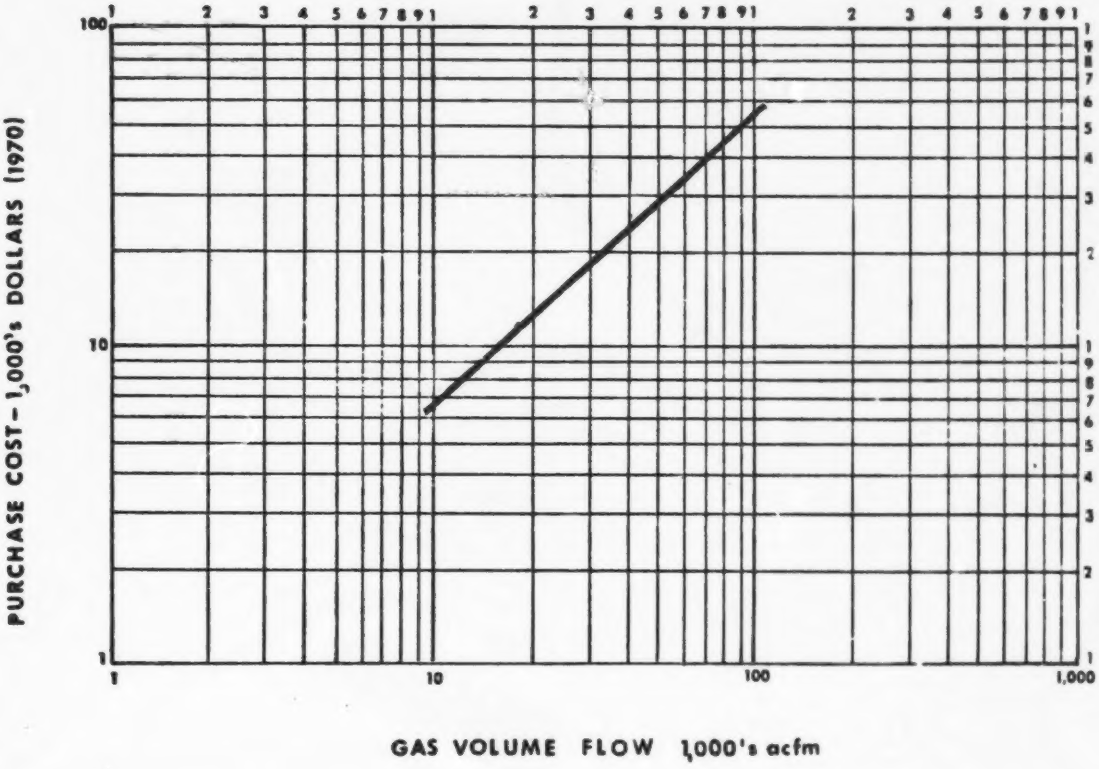
SOURCE-MANUFACTURER

FIGURE 8B-8

REMOVAL EQUIPMENT PURCHASE COST

(1970)

WET CENTRIFUGAL SCRUBBER (TYPE 304 STAINLESS)



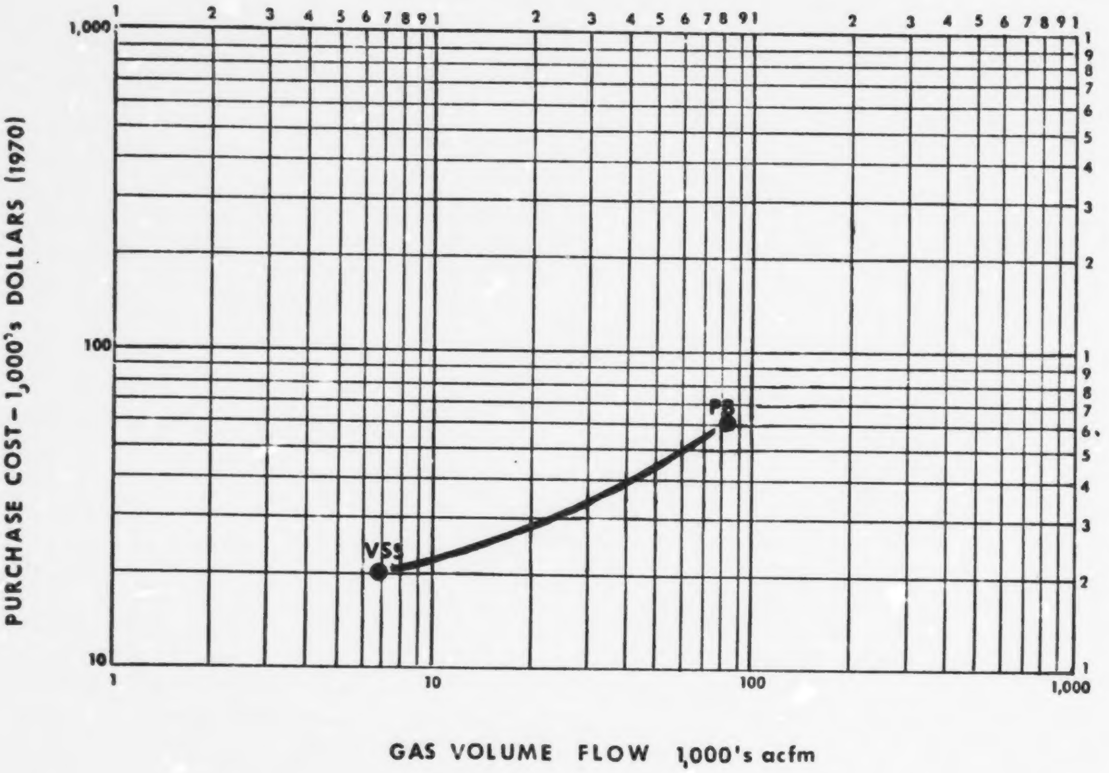
SOURCE—MANUFACTURER

FIGURE 8B-9

REMOVAL EQUIPMENT PURCHASE COST

(1970)

VENTURI SCRUBBER



SOURCE – MANUFACTURER

FIGURE 8-B-10

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

CHAMBER SCRUBBER

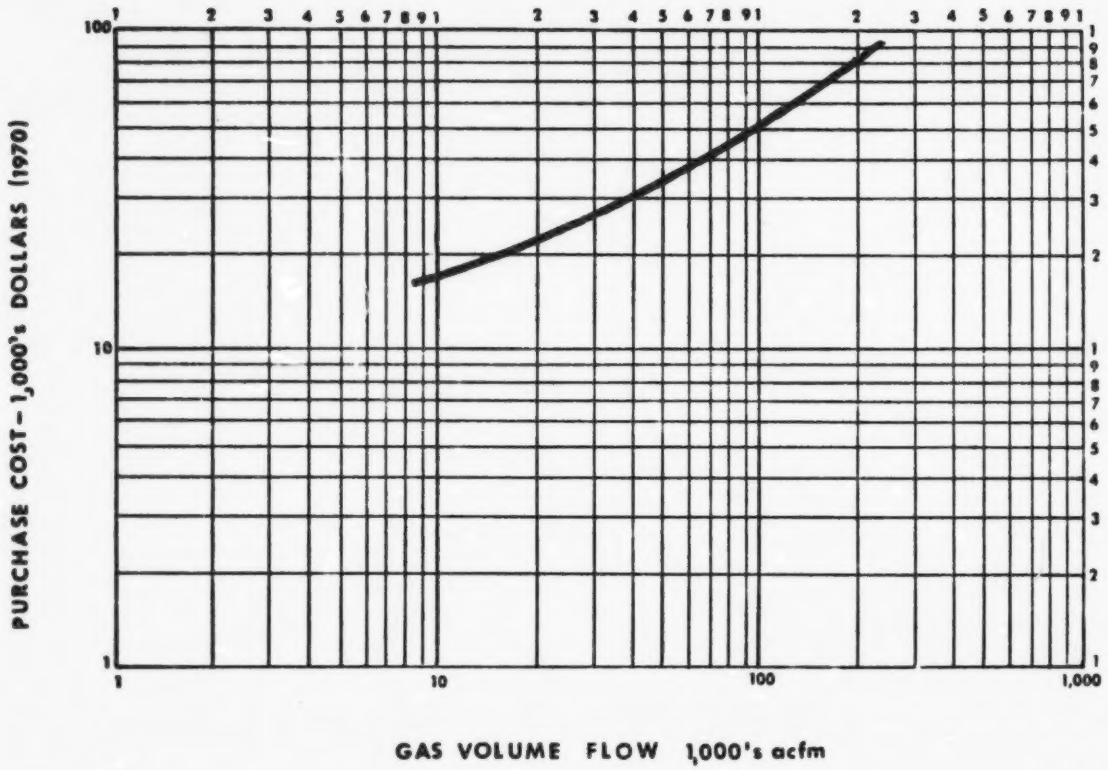
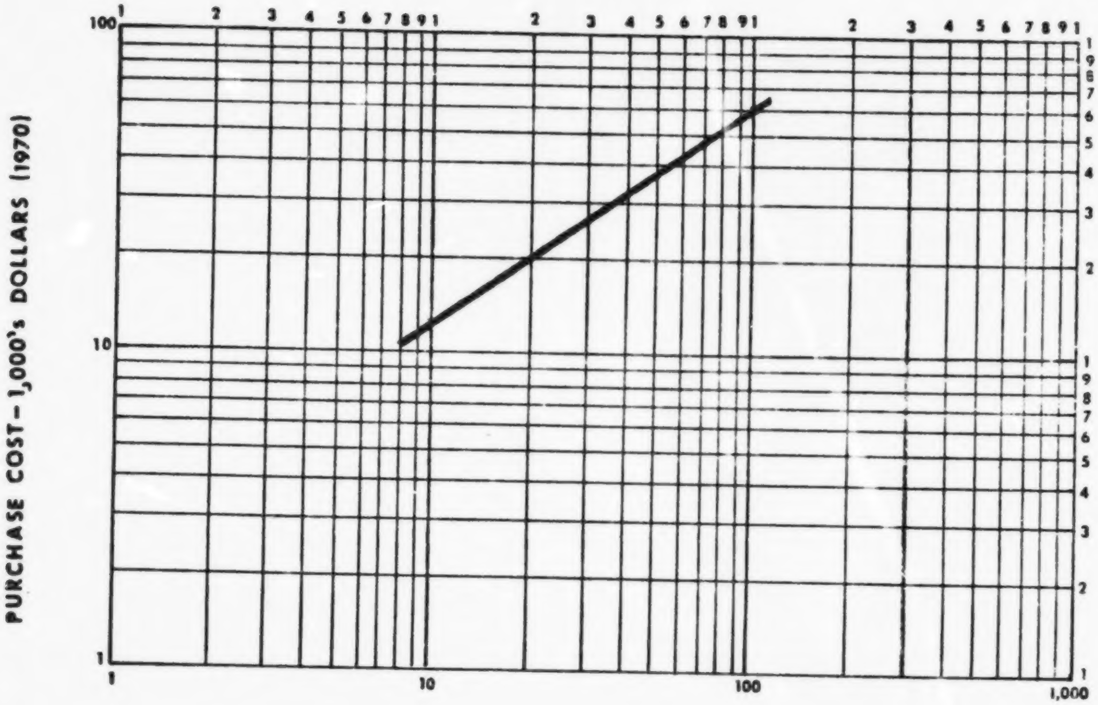


FIGURE 8B-11
REMOVAL EQUIPMENT
PURCHASE COST
(1970)

WET IMPINGEMENT SCRUBBER
(STAINLESS STEEL)



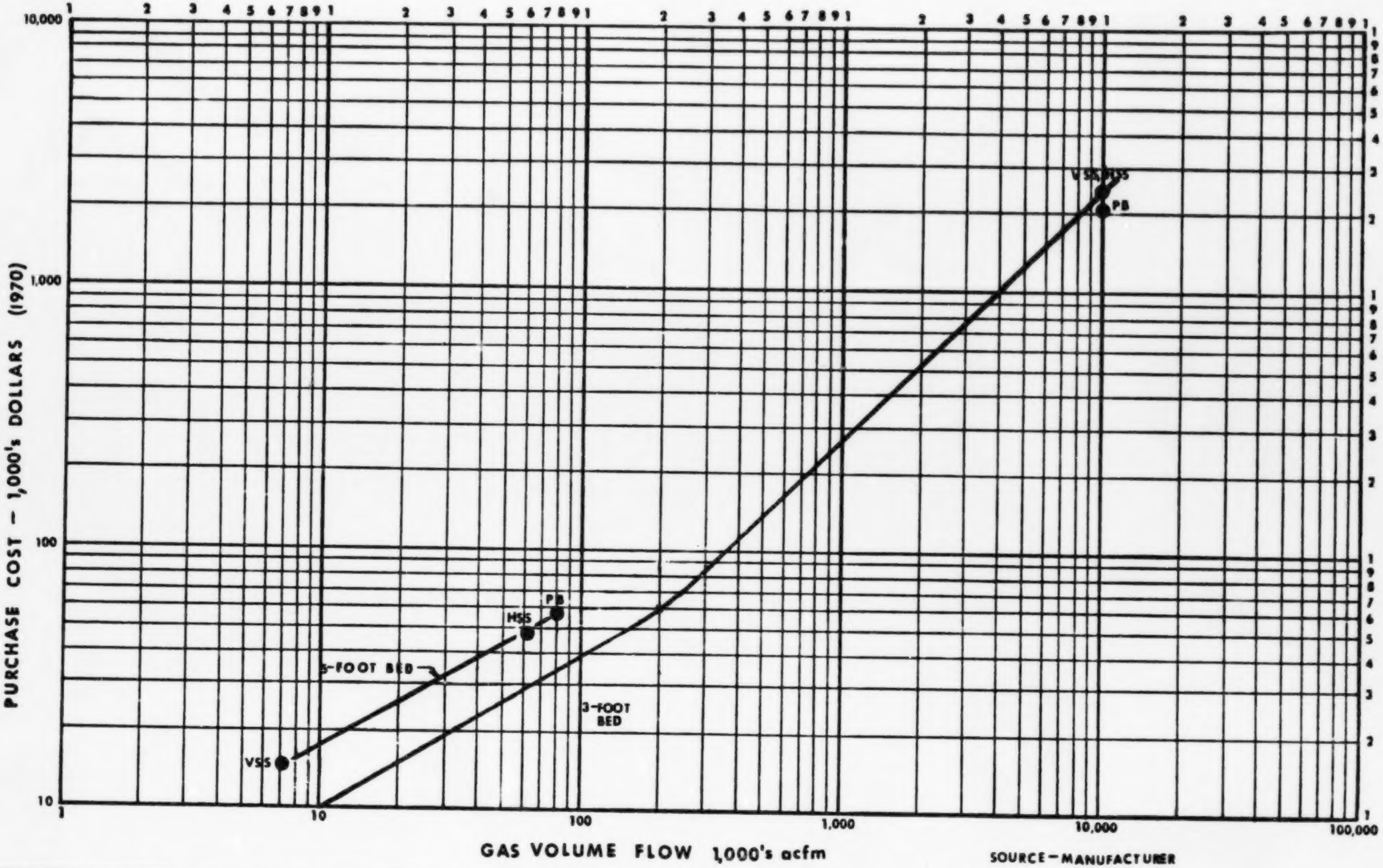
GAS VOLUME FLOW 1,000's acfm

SOURCE – MANUFACTURER

FIGURE 8B-12

PURCHASE COST REMOVAL EQUIPMENT (1970)

CROSS FLOW PACKED BED

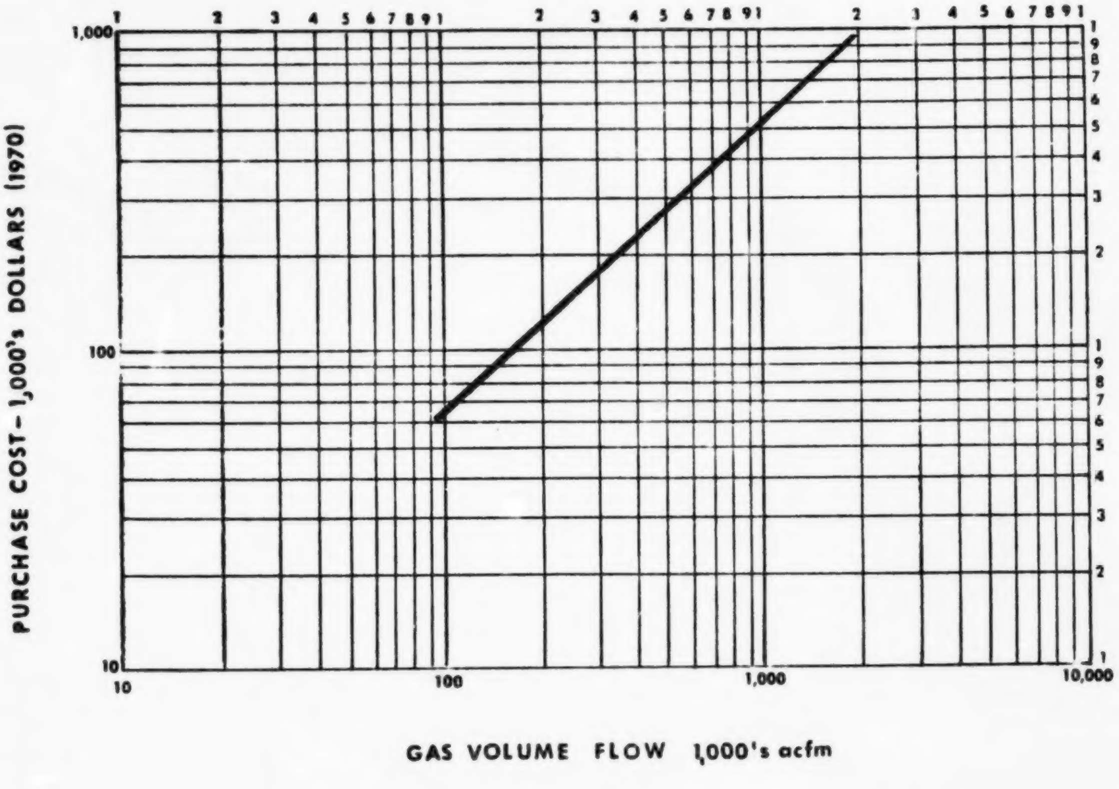


SOURCE – MANUFACTURER

FIGURE 8B-13

REMOVAL EQUIPMENT
PURCHASE COST
(1970)

FLOATING BED WET SCRUBBER



SOURCE-MANUFACTURER

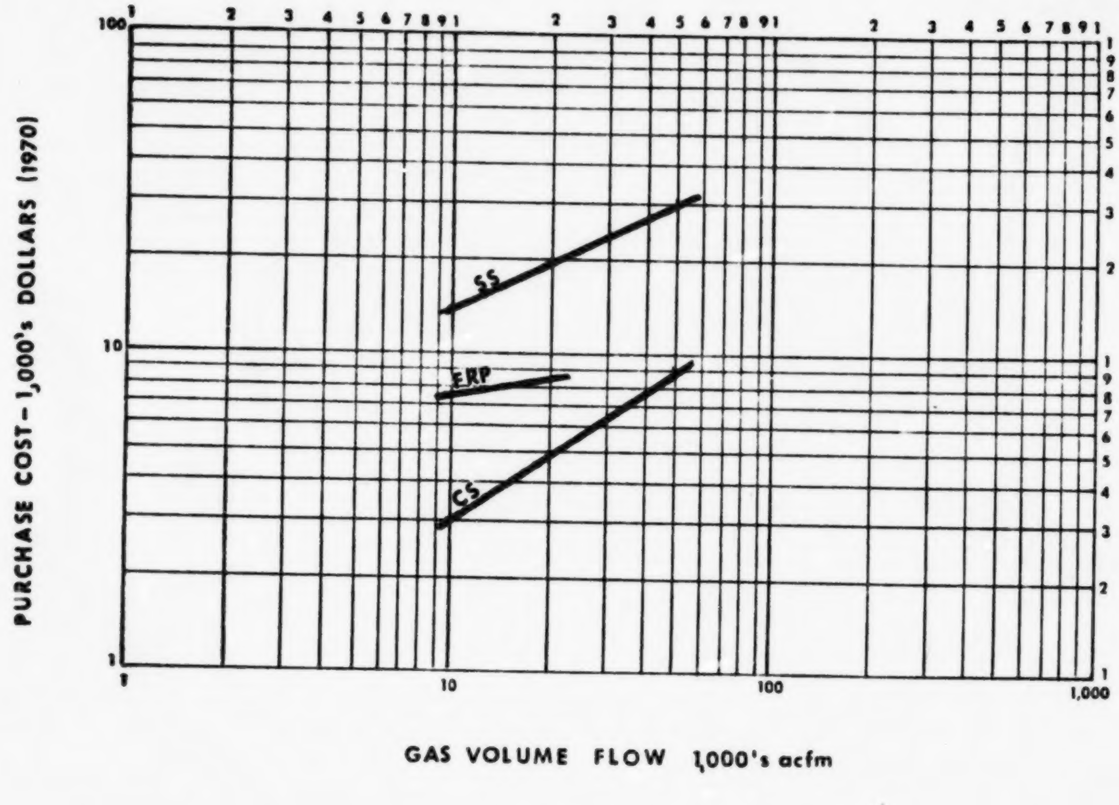
FIGURE 8B-14

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

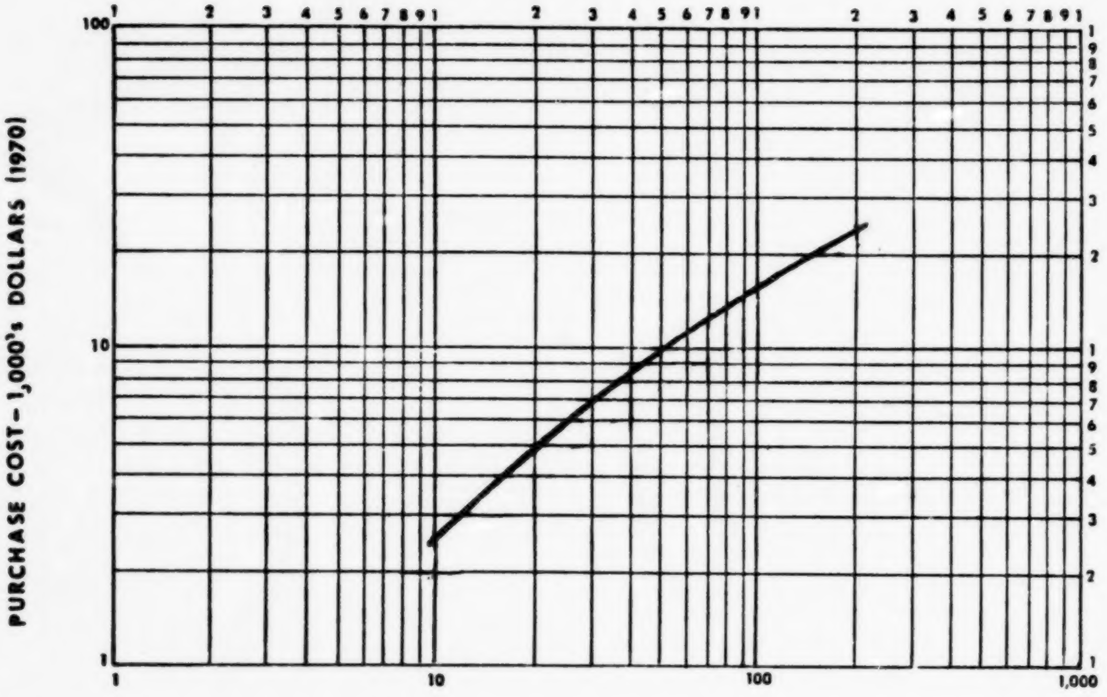
ORIFICE TYPE SCRUBBER



SOURCE—MANUFACTURER
SS – STAINLESS STEEL
FRP— FIBERGLASS REINFORCED PLASTIC
CS – CARBON STEEL

FIGURE 8B-15
REMOVAL EQUIPMENT
PURCHASE COST
(1970)

AXIAL FLOW FANS



GAS VOLUME FLOW 1,000's acfm

FAN PRESSURE 4.7 - 5.6 IN. WATER
SOURCE - MANUFACTURER

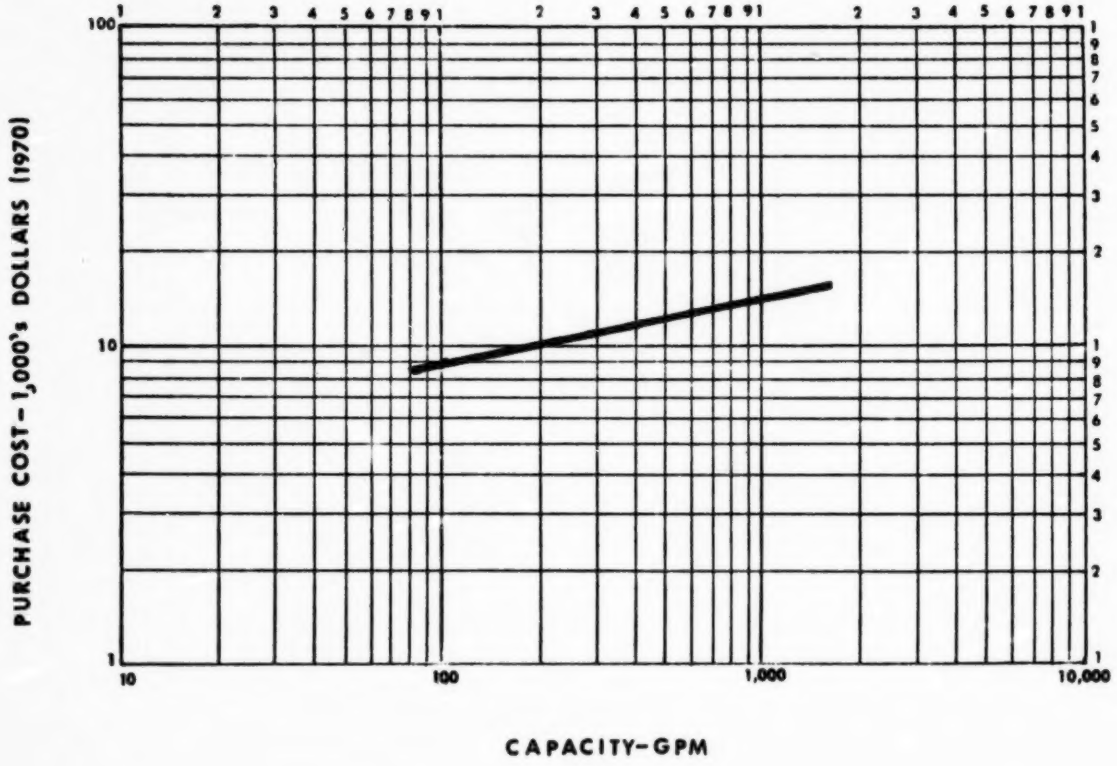
FIGURE 8B-16

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

LOW PRESSURE
SCRUBBER PUMP



SOURCE – MANUFACTURER

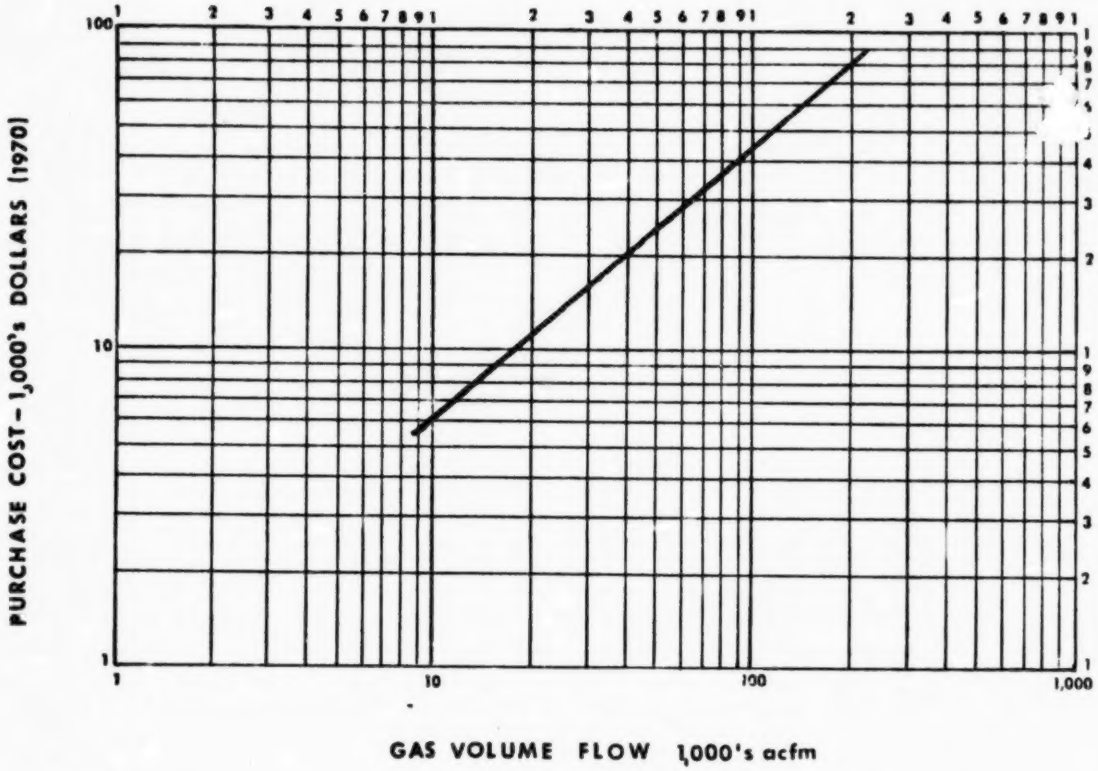
FIGURE 8B-17

REMOVAL EQUIPMENT

PURCHASE COST

(1970)

PUMP AND FAN MOTORS



FAN PRESSURE 6.0 in. water

SPRAY PRESSURE 15 psig

SOURCE - MANUFACTURER

Appendix 9A

Sample Calculation of Industry Control Improvement Costs

The pollution control practices representative of the various segments of the industry have been described by the models developed in Section 8 in such a way that modification from one model to another can be carried out and evaluated. The cost elements given in Tables 8.4a through 8.4c can be applied to such modification to determine the incremental costs, and Section 9.4 develops costs of upgrading the present level of control to several higher standards by summing the incremental costs so estimated.

The method of obtaining the incremental cost of upgrading is illustrated by the following example. It considers the portion of the industry represented by Model IA-6 (old), in which the emission control uses a multiple cyclone followed by a spray tower to treat the cell effluent of older type prebake cells collected in a primary system, and in which there is no secondary treatment. Improvement in control is achieved by conversion of the model to others with higher overall efficiencies by substitution of removal elements.

Example

Original Model - IA-6 (old)

Control System

Primary: Multiple tube cyclone followed by spray tower
Secondary: None

Industry Capacity, this model, - 542,000 tons per year
Effluent Fluorides - 12,305 tons per year
Overall Control Efficiency - 76.0%
Fluoride Emission 2,935 tons per year

Case I - Upgrade to Minimum 80% OCE

New Model - IA-5 (old)
Overall Control Efficiency 80.0%
Fluoride Emission 2,765 tons per year

Control System

Primary: Multiple cyclone followed by a cross flow packed bed scrubber.
Secondary: None

Modifications Required

a) Modify collection system to accomodate CFPB-5
b) Demolish spray tower
c) Install CFPB-5 with 1.12 times the model flow rate

Added Costs, per ton capacity (Ref. Table 8.4a)

	Capital	Annualized
a)	(1.60*)x($5.62) = $ 9.00	$0.72
b)	(0.75*)x($2.47) = 1.85	(2.37)
c)	(1.12 flow factor) x ($14.35) = 16.07	4.60
Added Model Costs	$26.92	$2.95
Adjustment for old plant, 15%	4.04	12% - 0.35
Net Added Costs	$30.96	$3.30

* Ref. Page 9-12 for cost factor.

Case II - Upgrade to Best Primary Technology

New Model - IA-1
Overall Control Efficiency - 84.4%
Fluoride Emission - 2,156 tons per year

Control System

Primary: Fluid Bed Dry Scrubber
Secondary: None

Modifications Required

a) Modify collection system
b) Demolish multiple cyclone
c) Demolish spray tower
d) Abandon Water treatment
e) Add FBDS

Added Costs per ton capacity (Ref. Table 8.4a)

	Capital			Annualized
a)	(1.60*)x($5.62) =	$ 9.00		$0.72
b)	(0.75*)x($0.87) =	0.65		3.12
c)	(0.75*)x($2.47) =	1.85		(2.37)
d)				(1.63)
e)	(1.12) x(40.07) =	44.88		3.23
	Added Model Costs	$56.38		$3.07
	Adjustment for old plant, 15%	8.46	12% -	0.37
	Net Added Costs	$64.84		$3.44

* Ref. Page 9-12

Case III - Upgrade to Industry Minimum 90% OCE

New Model - IB-4,9
Overall Control Efficiency - 90.9%
Fluoride Emission - 1,258 tons per year

Control System

Primary: Dry electrostatic precipitator followed by existing spray tower.
Secondary: Spray screen.

Modification Required

a) Modify collection system
b) Demolish multiple cyclones
c) Add DESP with 1.12 times the model flow rate
d) Add secondary spray screen
e) Add secondary water treatment.

Added Costs, per ton capacity (Ref. Table 8.4a)

	Capital			Annualized
a)	(1.60*) x($5.62) =	$ 9.00		$ 0.72
b)	(0.75*)x($0.87) =	0.65		3.12
c)	(1.12) x($17.24) =	19.30		(0.25)
d)		37.10		12.99
e)		5.76		2.34
	Added Model Costs	$71.82		$18.92
	Adjustment for old plant, 15%	10.77	12% -	2.27
	Net Added Costs	$82.59		$21.19

* Ref. Page 9-12

Case IV - Upgrade to Best Available Technology

New Model - IB-1, 9
Overall Control Efficiency - 93.0%
Fluoride Emission 968 tons per year

Control System

Primary: Fluidized Bed Dry Scrubber
Secondary: Spray Screen

Modification Required

a) Modify collection system to accomodate FBDS
b) Demolish MC
c) Demolish ST
d) Add FBDS
e) Abandon Primary Water Treatment
f) Add SS secondary
g) Add Secondary Water Treatment

Added Costs, per ton capacity (Ref. Table 8.4a)

	Capital			Annualized
a)	(1.60*)x($5.62) =	$ 9.00		$ 0.72
b)	(0.75*)x($0.87) =	0.65		3.12
c)	(0.75*)x($2.47) =	1.85		(2.37)
d)	(1.12) x($40.07)=	44.88		3.23
e)		-		(1.63)
f)		37.10		12.99
g)		5.76		2.34
	Added Model Costs	$99.24		$18.40
	Adjustment for old plant, 15%	14.89	12% -	2.21
	Net Added Costs	$114.13		$20.61

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* Ref. Page 9-12